Air Quality Monitoring in the Caroline and Sundre Area
Final Report - Spring 1997 to Spring 1998

Alberta Environment conducted an air quality monitoring survey in the Caroline and Sundre area of West Central Alberta from April 1997 to April 1998. The objectives of the program were to: (1) determine air pollutants levels in the vicinity of industrial facilities in the area; (2) detect the influence of elevation and topography on air pollutant concentrations; and (3) identify some of the specific sulphur and hydrocarbon compounds that may be responsible for complaints. This monitoring survey was initiated in response to concerns raised by area residents through the Caroline Interrogatory Process.

The Caroline/Sundre air quality monitoring survey was composed of two parts. In Part 1, the Alberta Environment Mobile Air Monitoring Laboratory (MAML) was used to monitor air quality downwind of industrial facilities in the area on 14 days in the spring, summer and fall of 1997, and in the winter and spring of 1998. Air quality parameters monitored by the MAML included sulphur dioxide, hydrogen sulphide, total reduced sulphur, hydrocarbons, particulates, oxides of nitrogen, ozone and carbon monoxide.

In Part 2, passive methods (no power required) were used to monitor for sulphur dioxide and volatile organic compounds. Passive sulphur dioxide samples were collected on a monthly basis at 12 locations in the area from November 1997 to April 1998. Odour triggered volatile organic compound samples were collected as a 6 to 36 hour concentration at seven locations between October 1997 and April 1998. These passive monitoring locations were selected in consultation with local residents.

The cooperation and assistance of citizens in the Caroline and Sundre areas was essential to the success of this monitoring survey. Alberta Environment would like to thank the following residents for allowing monitoring to be conducted on their property and for participating in collecting air quality samples. These individuals are D. Brown, E. Fauville, W. Johnson, T. Kelley, J. Macklin, W. McMurtry, L. Paget and L. Ringland.

Major Findings

(1) Concentrations of air pollutants measured in the Caroline/Sundre survey were below Alberta's air quality guidelines. Maximum one-hour concentrations were:

- 25% of the one-hour guideline for sulphur dioxide;
- 80% of the one-hour guideline for hydrogen sulphide;
- 72% of the one-hour guideline for ozone;
- 19% of the one-hour guideline for nitrogen dioxide; and
- 7% of the one-hour guideline for carbon monoxide.

(2) Elevated sulphur dioxide and hydrogen sulphide concentrations were recorded downwind of industrial facilities. The maximum one-hour sulphur dioxide concentration of 0.043 ppm (parts per million) was measured downwind of the Shell Caroline gas plant and the maximum one-hour hydrogen sulphide concentration of 0.008 ppm was observed downwind of the Shell Shantz facility. Alberta's one-hour guidelines for sulphur dioxide and hydrogen sulphide are 0.170 and 0.010 ppm, respectively.

(3) Sulphur dioxide concentrations from passive samplers did not show an obvious relationship to elevation and topography. The highest one-month and six-month average values were recorded at the meteorological station located 1 km west of the Shell Caroline gas plant. Maximum one-month and six-month levels at this location were 6.6 and 3.4 ppb (parts per billion), respectively. The annual guideline for sulphur dioxide is 10 ppb.

(4) Elevated concentrations of individual volatile organic compounds were measured in samples collected during well testing and flaring events. The maximum benzene concentration observed during these events was 14.6 $\mu g/m^3$ (micrograms per cubic meter). This value is lower than Alberta's interim one-hour guideline for benzene of 30 $\mu g/m^3$. Concentrations of toluene, ethylbenzene and xylenes in the Caroline/Sundre area were very low compared to Ontario's point impingement standards for these chemicals.

ISBN No. 0-7785-0599-5
Pub No. T/449

Part 1: Monitoring Using the Mobile Air Monitoring Laboratory

The Alberta Environment Mobile Air Monitoring Laboratory (MAML) was used to monitor air quality for close to 80 hours, on 14 days, in the Caroline/Sundre area between April 1997 and April 1998. The focus of this monitoring was to collect air quality data downwind of industrial facilities and at communities in the area. Air quality was monitored on the following dates representing the spring, summer, fall and winter seasons:

- spring (April 22 and 23, 1997; April 27, 28 and 29, 1998);
- summer (July 21, 22 and 23, 1997);
- fall (October 28, 29 and 30, 1997); and
- winter (January 27, 28 and 29, 1998).

The MAML was used to monitor air quality in a broad rural area from Township 31 in the south to Township 36 in the north and Range 4 in the east to Range 7 in the west. Air quality data was collected at over 50 locations in this region. Monitoring was conducted for a minimum of one hour at each of these locations to allow comparison with the air quality guidelines. For the purpose of presentation, air quality data collected at these locations was grouped into 13 general areas.

Monitoring Method

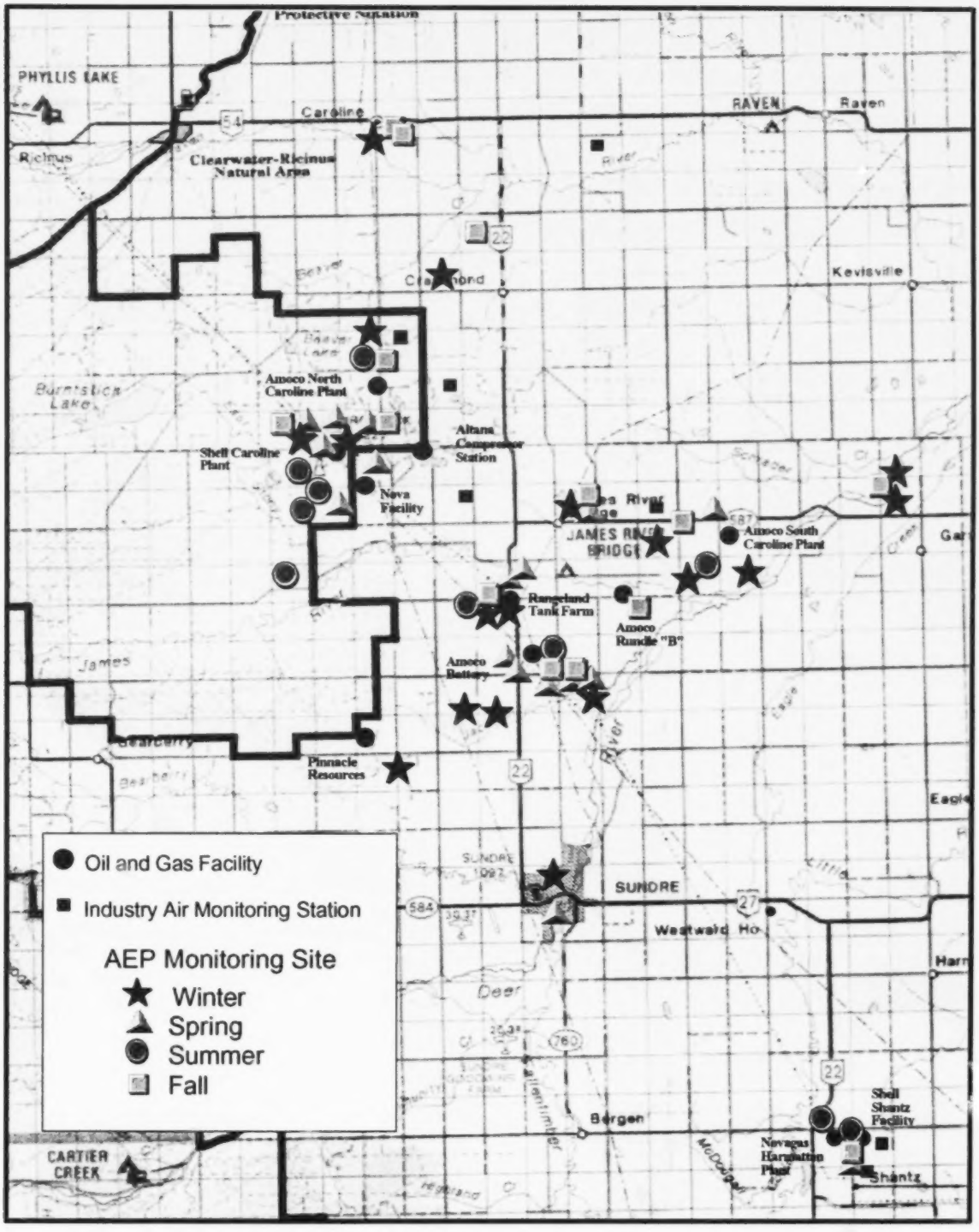
The MAML is a 27-foot (8.2 m) vehicle that has been specially designed and equipped to measure air quality. It houses a variety of instruments that sample the air at specified time or distance intervals, and analyze the samples quickly and reliably. The MAML is equipped with:

- a dual computer system with a custom program to control the measurement and storage of air samples from each analyzer;
- a GPS (Global Positioning System) that will identify the MAML's location as it moves around Alberta;
- an exhaust scrubbing system that minimizes emissions from the vehicle; and
- two on-board generators that are also equipped with exhaust scrubbers.

The following parameters were measured by the MAML in the Caroline/Sundre area:

- sulphur dioxide (SO_2);
- hydrogen sulphide (H_2S);
- total reduced sulphur (TRS);
- total hydrocarbons (THC);
- reactive hydrocarbons (RHC);
- methane (CH_4);
- ozone (O_3);
- nitrogen dioxide (NO_2);
- nitric oxide (NO);
- total oxides of nitrogen (NO_x);
- total suspended particulates (TSP);
- inhalable particulates (PM_{10});
- respirable particulates ($PM_{2.5}$);
- carbon monoxide (CO);
- wind direction and speed;
- temperature; and
- relative humidity.

Alberta Environment's Mobile Air Monitoring Laboratory



Caroline/Sundre Area MAML Monitoring Sites

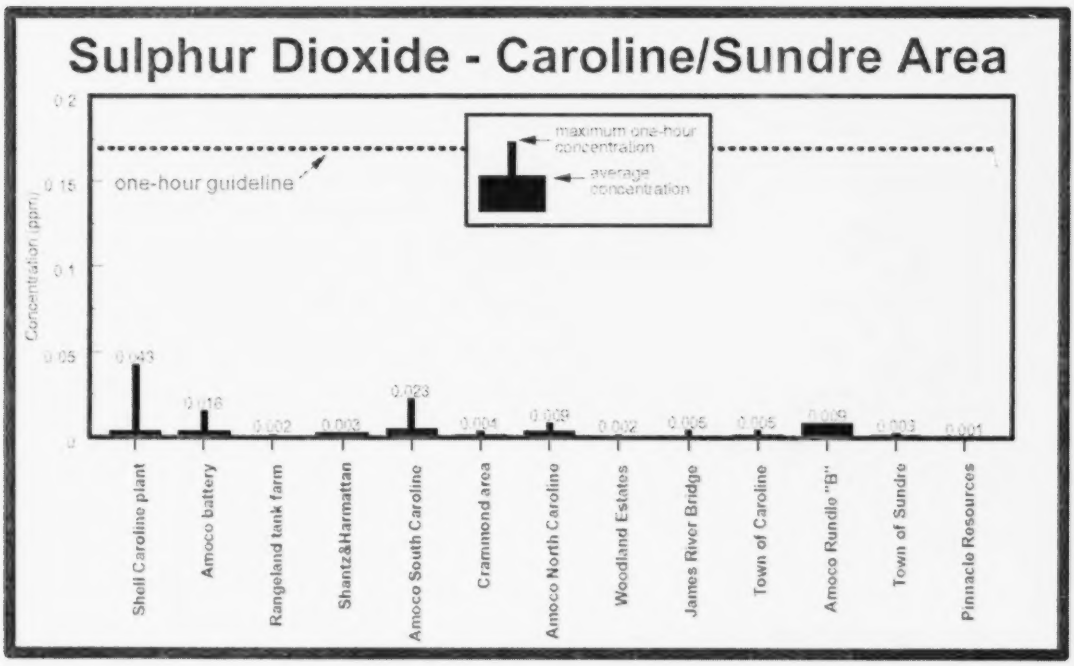
Sulphur Dioxide (SO_2)

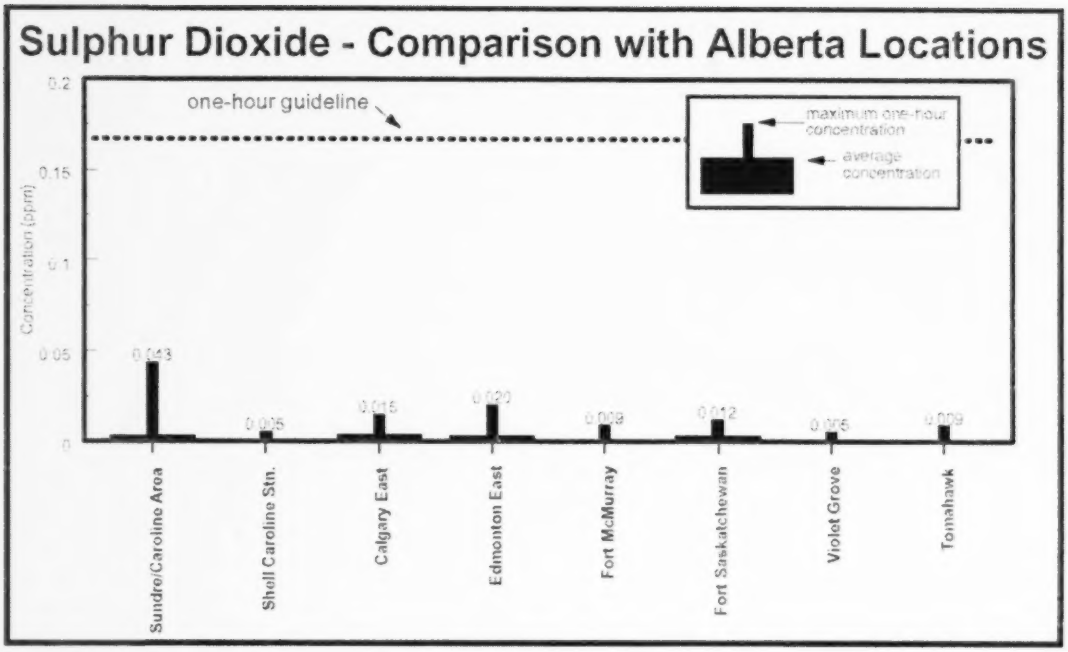
max. one-hour concentration	one-hour guideline
0.043 ppm	0.170 ppm

Sulphur dioxide (SO_2) is a colourless gas with a pungent odour. In Alberta, the major sources of SO_2 are natural gas processing plants, oil sands facilities, and power plants. Other sources include gas plant flares, oil refineries, pulp and paper mills and fertilizer plants.

Elevated SO_2 concentrations were evident downwind of industrial facilities in the Caroline/Sundre region. The maximum one-hour average concentration was measured 0.5 km downwind of the Shell Caroline gas plant on April 23, 1997 (0.043 ppm). Slightly elevated SO_2 values were also recorded in the vicinity of the Amoco South Caroline gas plant (0.023 ppm) and Amoco battery (0.016 ppm). These maximum one-hour values occurred on July 23, 1997 at the Amoco battery and on April 27, 1998 at the Amoco South Caroline gas plant. Peak five-minute SO_2 concentrations in the vicinity of the Shell Caroline gas plant, Amoco South Caroline gas plant and the Amoco battery were 0.058, 0.122 and 0.055 ppm, respectively. Maximum one-hour and peak five-minute SO_2 concentrations in the Caroline/Sundre area were below Alberta's one-hour guideline of 0.170 ppm.

Average SO_2 concentrations for the entire monitoring period in the Caroline/Sundre area (0.003 ppm) were similar to those recorded at the Alberta Environment Edmonton East (0.003 ppm), Calgary East (0.004 ppm) and Fort Saskatchewan (0.003 ppm) monitoring stations. However, maximum one-hour average SO_2 values in the Sundre/Caroline area were higher than those recorded at other rural locations in Alberta. For example, the maximum one-hour average SO_2 concentrations at the Tomahawk and Violet Grove stations for the same time period were 0.009 and 0.005 ppm, respectively, compared to a maximum one-hour value of 0.043 ppm measured in the Caroline/Sundre area. The Tomahawk (25 km northeast of Drayton Valley) and Violet Grove (10 km southwest of Drayton Valley) stations are operated by the West Central Airshed Society (WCAS). Higher SO_2 values recorded by the MAML in the Caroline/Sundre area were due to monitoring in close proximity and directly downwind of industrial facilities in the area.





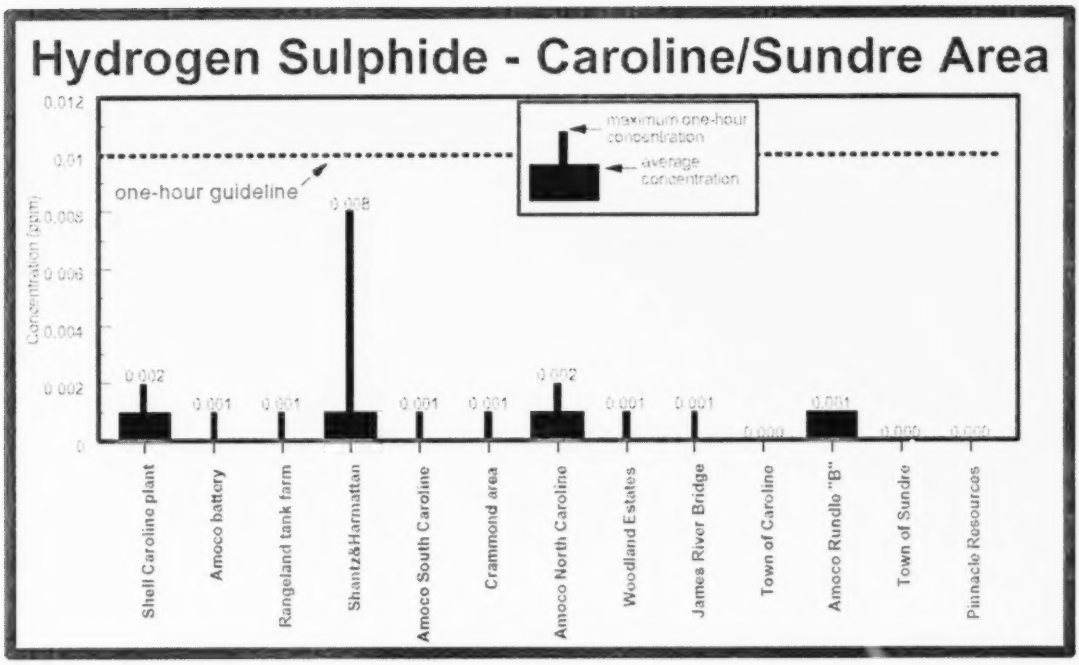
Hydrogen Sulphide and Total Reduced Sulphur (H_2S and TRS)

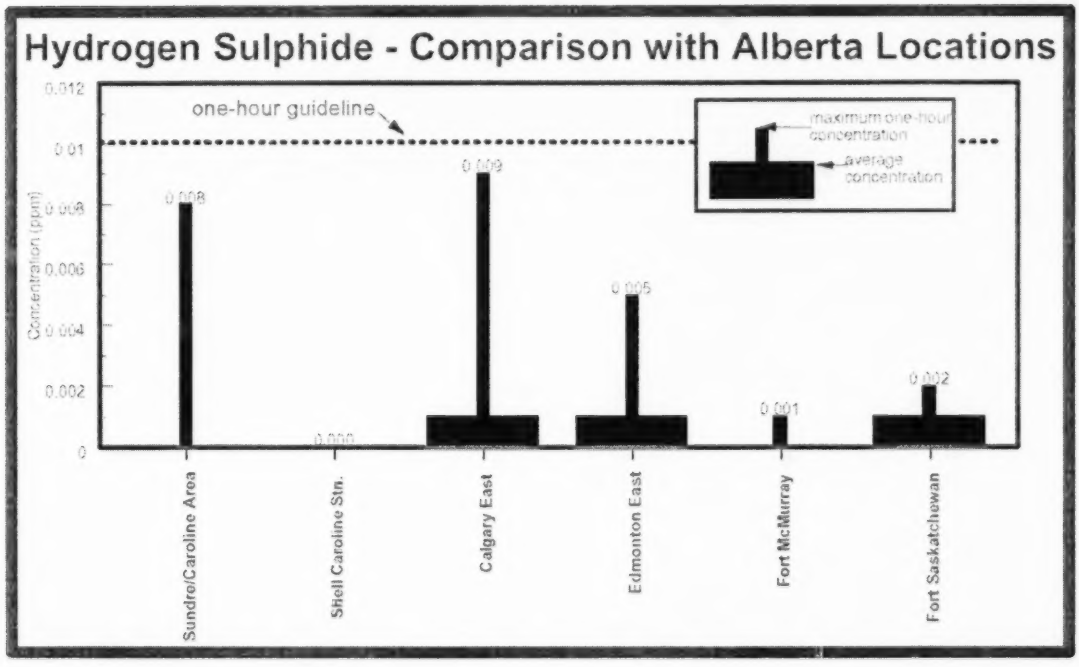
max. one-hour concentration	one-hour guideline
H_2S = 0.008 ppm TRS = 0.008 ppm	0.010 ppm no guideline

Hydrogen sulphide (H_2S) is a colourless gas with a rotten egg odour. Total reduced sulphur (TRS) includes hydrogen sulphide, mercaptans, dimethyl sulphide, dimethyl disulphide and other sulphur compounds. Sulphur dioxide is not included in the determination of TRS. Industrial sources of H_2S and TRS include fugitive emissions (leakages) from petroleum refineries, tank farms for unrefined petroleum products, natural gas plants, petrochemical plants, oil sands plants, sewage treatment facilities, pulp and paper plants that use the Kraft pulping process, and animal feedlots. Natural sources of H_2S include sulphur hot springs, sloughs, swamps and lakes.

H_2S and TRS concentrations were at or below the detection limit of the monitoring instrument most of the time in the Caroline/Sundre area. However, elevated H_2S and TRS values were recorded downwind of the Shell Shantz facility in the morning on July 21. The maximum one-hour and peak five-minute concentrations during this episode were 0.008 and 0.011 ppm, respectively. Concentrations of H_2S and TRS were 0.002 ppm or below for the remainder of the monitoring period. The one-hour guideline for H_2S is 0.010 ppm however; sensitive individuals can detect H_2S as an odour at concentrations as low as 0.003 ppm.

The overall average H_2S and TRS concentrations were very low in the Caroline/Sundre area based on data collected between April 1997 and April 1998. Overall average values at other Alberta monitoring stations were also very low for this time period (0.000 to 0.001 ppm). However, one-hour maximum H_2S values did approach the guideline at the Calgary East monitoring station (0.009 ppm). Air quality guidelines for H_2S are occasionally exceeded at the Calgary East and Edmonton East monitoring stations due to local sewage treatment plants and industrial facilities. TRS is not routinely monitored at Alberta Environment monitoring stations.


Hydrogen Sulphide - Caroline/Sundre Area
0.012
0.01
0.008
0.006
0.004
0.002
0
Concentration (ppm)
one-hour guideline
maximum one-hour concentration
average concentration
0.002
0.001
0.001
0.008
0.001
0.001
0.002
0.001
0.001
0.000
0.001
0.000
0.000
Shell Caroline plant
Amoco battery
Rangeland tank farm
Shantz&Harmattan
Amoco South Caroline
Crammond area
Amoco North Caroline
Woodland Estates
James River Bridge
Town of Caroline
Amoco Rundle "B"
Town of Sundre
Pinnacle Resources


Hydrogen Sulphide - Comparison with Alberta Locations
0.012
0.01
0.008
0.006
0.004
0.002
0
Concentration (ppm)
one-hour guideline
maximum one-hour concentration
average concentration
0.008
0.000
0.009
0.005
0.001
0.002
Sundre/Caroline Area
Shell Caroline Stn.
Calgary East
Edmonton East
Fort McMurray
Fort Saskatchewan

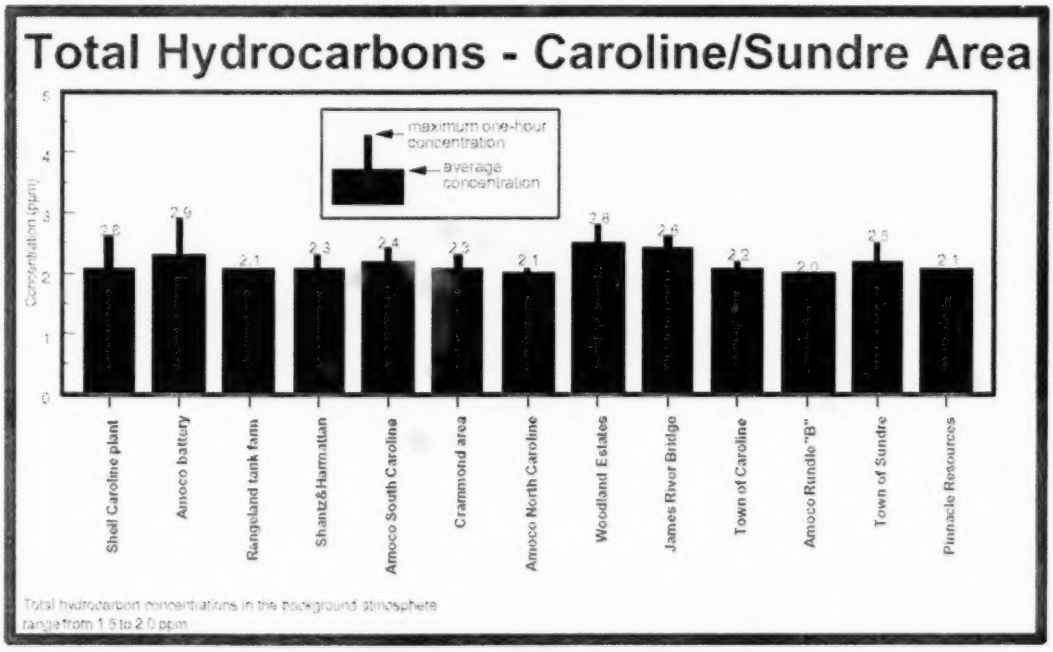
Hydrocarbons (THC, RHC and CH_4)

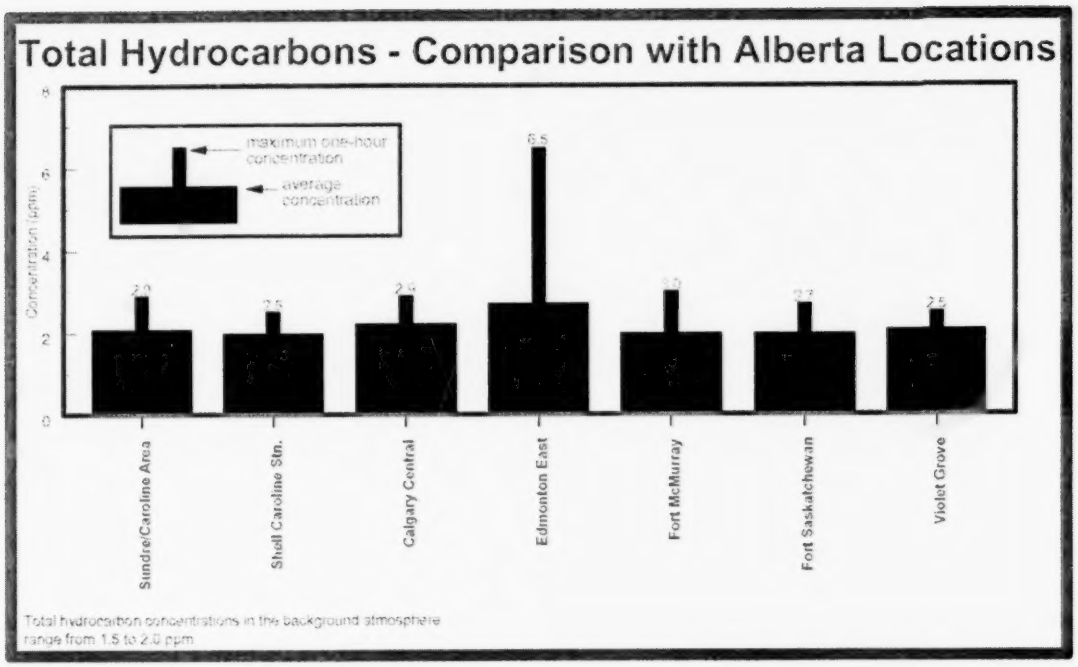
max. one-hour concentration	one-hour guideline
THC = 2.9 ppm	no guideline
RHC = 0.7 ppm	no guideline
CH_4 = 2.6 ppm	no guideline

The term "total hydrocarbons" (THC) refers to a broad family of chemicals that contain carbon and hydrogen atoms. Methane (CH_4), a non-reactive hydrocarbon, is the most common hydrocarbon in the earth's atmosphere. Specific reactive hydrocarbons (RHC) are important because: (1) they can react with oxides of nitrogen in the presence of sunlight to form ozone; and (2) they can be toxic at high concentrations to humans, animals or vegetation. Sources of hydrocarbons include vegetation, vehicular emissions, gasoline marketing and storage tanks, petroleum and chemical industries, dry cleaning, fireplaces, natural gas combustion and aircraft traffic.

Hydrocarbon levels were generally close to background levels in the Caroline/Sundre area during the monitoring period. However, slightly elevated values were recorded in the vicinity of industrial facilities and along major roads. The maximum one-hour average THC value (2.9 ppm) was recorded downwind of the Amoco battery in the morning on October 29, 1997. The highest one-hour average RHC concentrations were recorded near the Shell Caroline gas plant (in the evening of January 27) and at the James River Bridge Store (in the morning of January 28). The maximum one-hour average RHC value at these locations was 0.7 ppm. Based on data collected over the entire survey period, average hydrocarbon concentrations were highest in the Woodland Estates area (2.5 ppm) and at the James River Bridge Store (2.4 ppm). Slightly elevated hydrocarbon values at these locations were likely due to the combination of local vehicle traffic and industrial sources.

Hydrocarbon concentrations in the Caroline/Sundre area were similar to those observed at other Alberta monitoring stations. The overall average THC concentration in the Caroline/Sundre was the same as that recorded at the Violet Grove station operated by the WCAS for the same time period (2.1 ppm). However, THC values were well below those observed at the Edmonton East monitoring station. Average and maximum one-hour THC concentrations at the Edmonton East monitoring station were 2.7 and 6.5 ppm, respectively, for the same time period. Alberta Environment does not monitor for RHC and CH_4 on a routine basis at other locations in the province. Normal background THC concentrations are between 1.5 and 2.0 ppm.





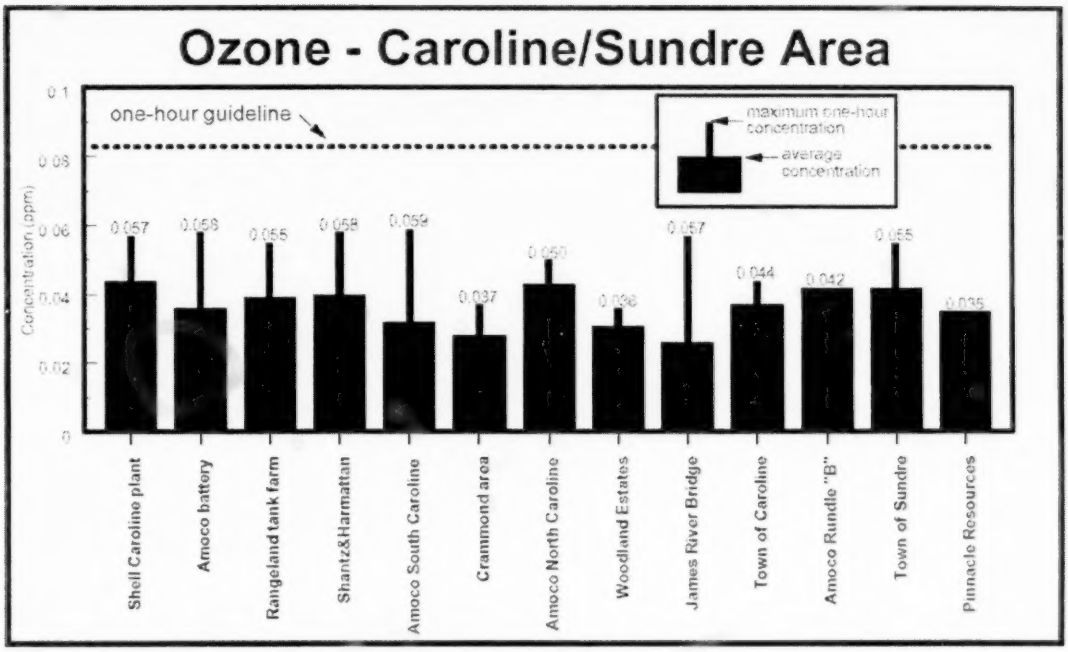
Ozone (O_3)

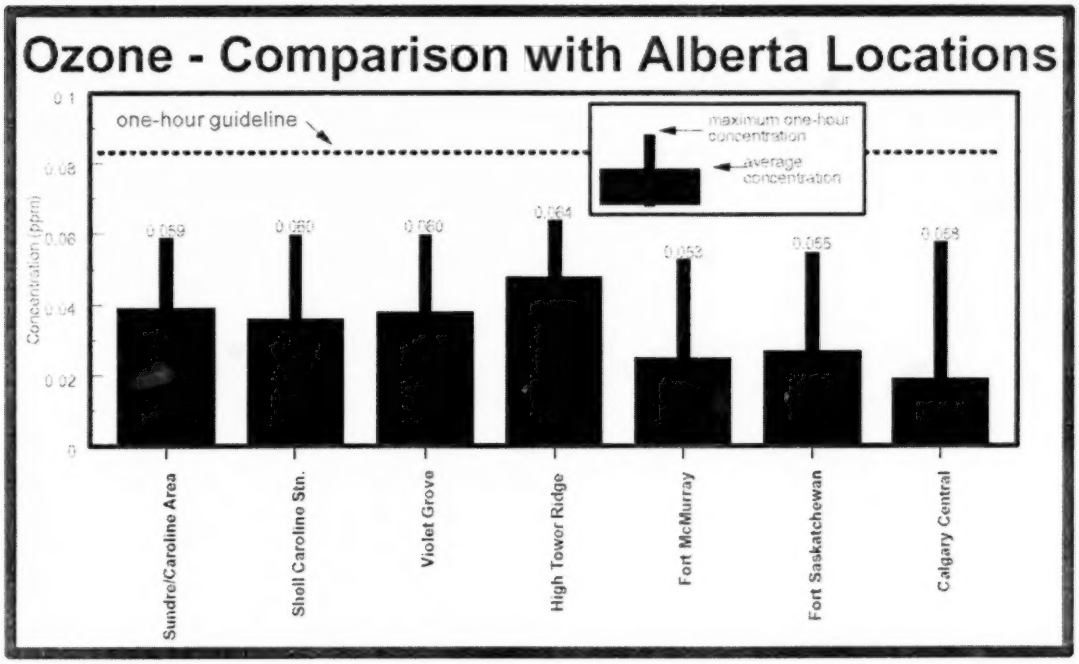
max. one-hour concentration	one-hour guideline
0.059 ppm	0.082 ppm

Ozone in the lower atmosphere is produced by: (1) the reaction of oxides of nitrogen and volatile organic compounds in the presence of sunlight, and (2) transport of O_3 from the upper atmosphere to ground level. Transport from the upper atmosphere is likely the dominant ozone producing process in the fall, winter and early spring seasons. O_3 concentrations are generally lower in urban centres due to the destruction of O_3 by nitric oxide.

O_3 concentrations followed the typical daily and seasonal variations in the Caroline/Sundre area. Maximum concentrations were generally recorded in the late afternoon and in the spring and summer seasons. The maximum one-hour average O_3 concentration (0.059 ppm) was recorded in the afternoon of April 29, 1998 in the vicinity of the Amoco South Caroline gas plant. Maximum one-hour O_3 concentrations between 0.055 and 0.060 ppm were also recorded in the afternoon on other spring survey days in 1997 and 1998.

O_3 concentrations in the Caroline/Sundre area were similar to those recorded at other rural locations in Alberta for the same time period. The average O_3 value in the Caroline/Sundre area was 0.039 ppm which is close to that recorded at the WCAS Violet Grove (0.038 ppm) and Shell Caroline Schmiemann (0.036 ppm) monitoring stations for the same time period. However, O_3 values in the Caroline/Sundre area were lower than those recorded at the WCAS Hightower Ridge station (65 km west-northwest of Hinton) where the average and maximum one-hour O_3 values were 0.048 and 0.064 ppm, respectively, for the same time period. Lower O_3 concentrations were observed at locations influenced by urban sources such as vehicle exhaust emissions (Edmonton, Calgary, Fort Saskatchewan and Fort McMurray). As mentioned earlier, nitric oxide emitted by vehicles will destroy O_3 that is present in the natural atmosphere.


Ozone - Caroline/Sundre Area
one-hour guideline
maximum one-hour concentration
average concentration
Concentration (ppm)
0.1
0.08
0.06
0.04
0.02
0
0.057
0.056
0.055
0.058
0.059
0.037
0.050
0.036
0.057
0.044
0.042
0.055
0.035
Shell Caroline plant
Amoco battery
Rangeland tank farm
Shantz&Harmattan
Amoco South Caroline
Crammond area
Amoco North Caroline
Woodland Estates
James River Bridge
Town of Caroline
Amoco Rundle "B"
Town of Sundre
Pinnacle Resources


Ozone - Comparison with Alberta Locations
one-hour guideline
maximum one-hour concentration
average concentration
Concentration (ppm)
0.1
0.08
0.06
0.04
0.02
0
0.059
0.060
0.060
0.064
0.052
0.055
0.059
Sundre/Caroline Area
Shell Caroline Stn.
Violet Grove
High Tower Ridge
Fort McMurray
Fort Saskatchewan
Calgary Central

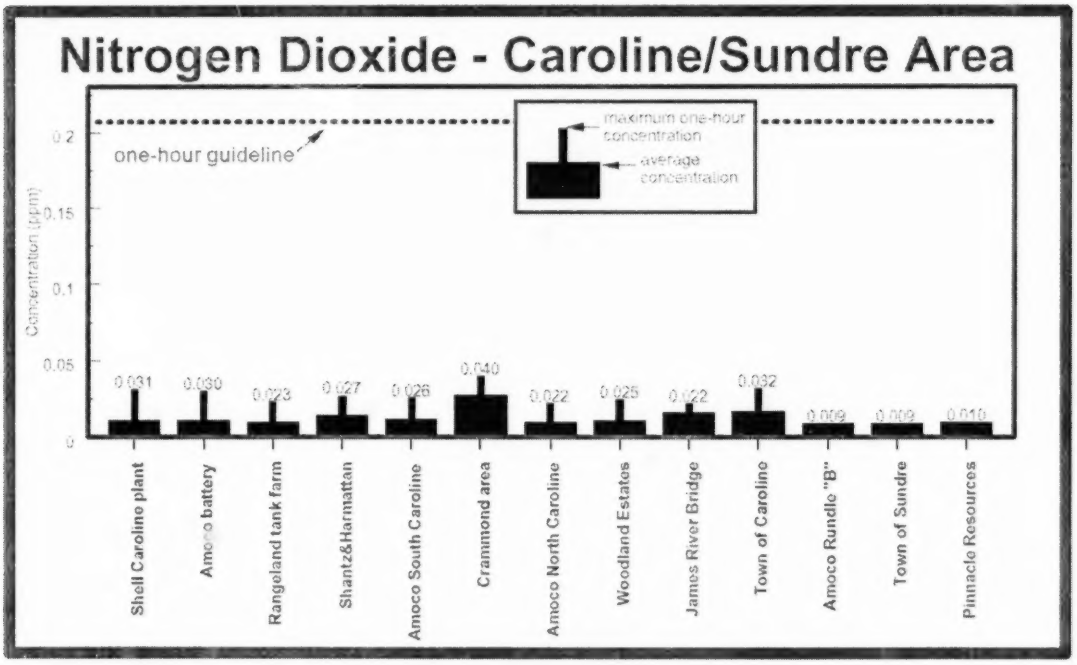
Oxides of Nitrogen (NO_2, NO, NO_x)

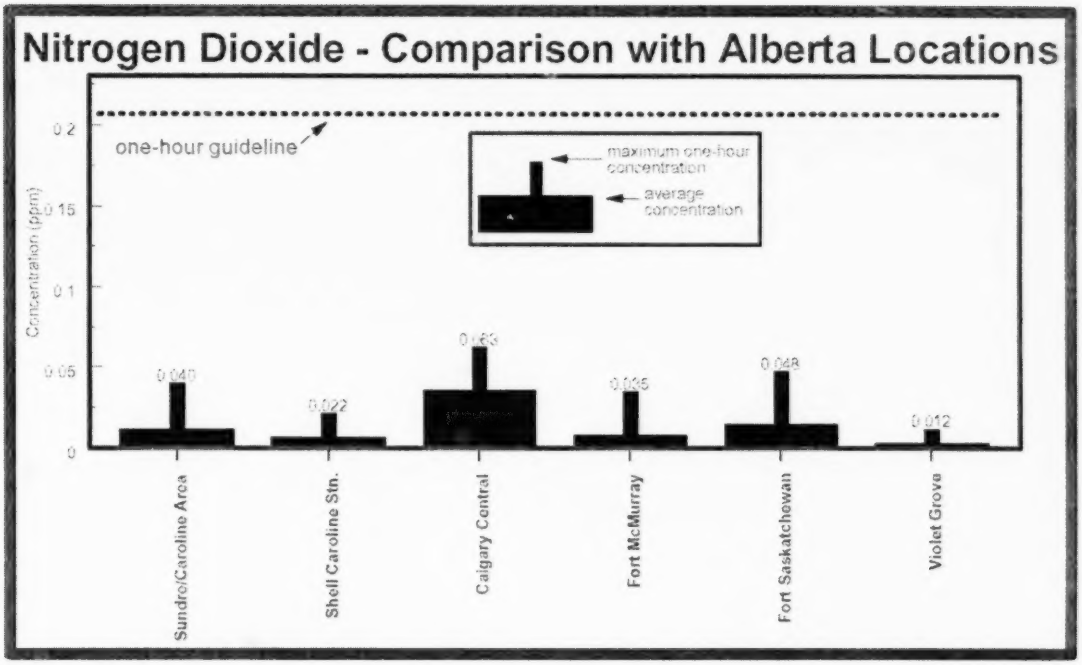
max. one-hour concentration	one-hour guideline
NO_2 = 0.040 ppm	0.210 ppm
NO = 0.047 ppm	no guideline
NO_x = 0.086 ppm	no guideline

Oxides of nitrogen (NO_x) are the total of nitrogen dioxide (NO_2) and nitric oxide (NO). During high temperature combustion - as in the burning of natural gas, coal, oil and gasoline - atmospheric nitrogen may combine with molecular oxygen to form NO. NO is colourless and odourless. Most NO in the ambient air is oxidized to form NO_2. NO_2 is a reddish-brown gas with a pungent odour. The major source of oxides of nitrogen in urban areas is vehicle exhaust emissions. Processes associated with the oil and gas industry also emit oxides of nitrogen into the atmosphere.

The maximum one-hour average NO_2 concentration (0.040 ppm) was recorded in the Crammond area in the afternoon on January 27. The second highest NO_2 concentration (0.032 ppm) was measured in the community of Caroline just before noon on October 30. One-hour average NO_2 values close to 0.030 ppm were also recorded near the Shell Caroline gas plant and the Amoco battery. NO_2 values in these areas were very low compared to the one-hour guideline of 0.210 ppm. The highest NO concentrations were recorded in the vicinity of Amoco battery (0.047 ppm), the Crammond area (0.045 ppm), the James River Bridge Store (0.043 ppm) and the Shell Caroline gas plant (0.042 ppm).

Oxides of nitrogen concentrations were low compared to values recorded in Calgary for the same time period. For example, the average NO_2 concentration for the entire monitoring period in the Caroline/Sundre area was 0.012 ppm compared to 0.036 ppm at the Calgary Central and East monitoring stations. NO_2 values in the Caroline/Sundre area were higher in than at the rural station operated by the WCAS near Violet Grove where the average value for the period was 0.003 ppm. The primary source of oxides of nitrogen in the Caroline/Sundre area is vehicle exhaust emissions from local traffic. However, oxides of nitrogen are also emitted by industries in the area.





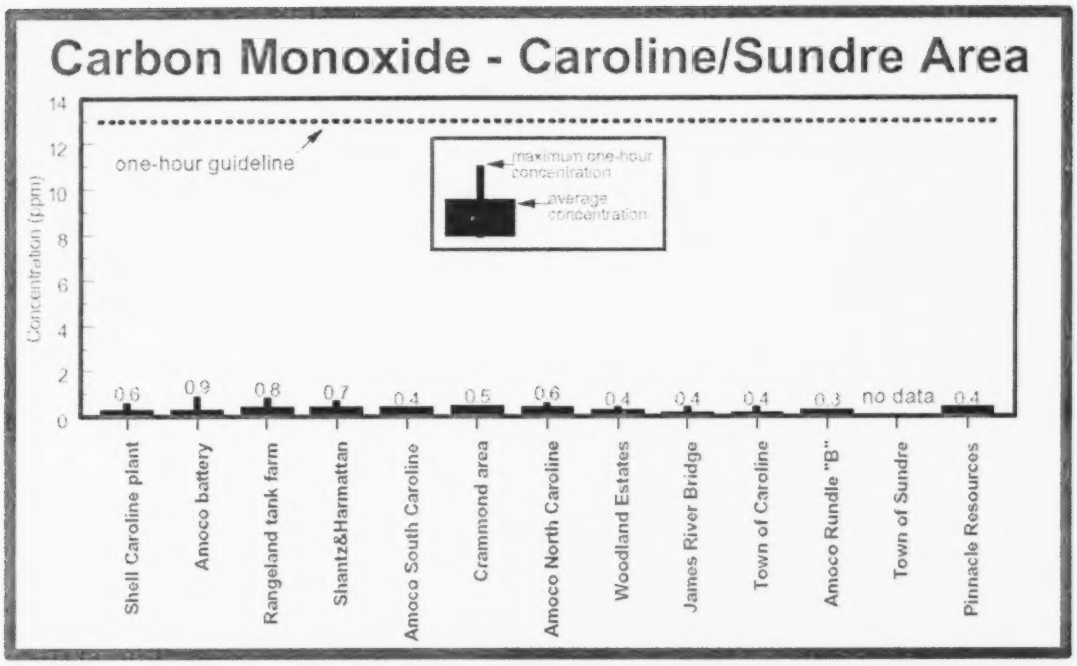
Carbon Monoxide (CO)

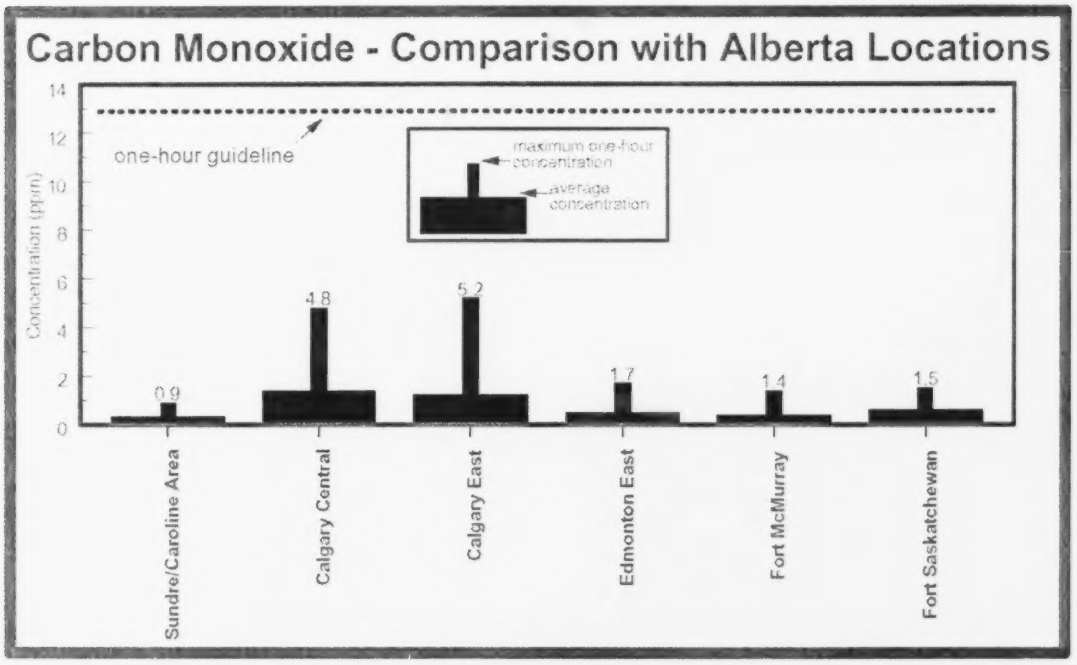
max. one-hour concentration	one-hour guideline
0.9 ppm	13 ppm

Carbon monoxide is a colourless, odourless gas emitted into the atmosphere primarily by motor vehicles. Minor sources include fireplaces, industry, aircraft and natural gas combustion.

Carbon monoxide values were very low during the entire survey period in the Caroline/Sundre area. The maximum one-hour concentration of 0.9 ppm was recorded near the Amoco battery in the afternoon of April 21. This maximum value is only 7% of the one-hour guideline. Carbon monoxide values were not monitored in the Caroline/Sundre area on October 28 and 29, 1997 and in April of 1998 due to an instrument malfunction.

Carbon monoxide values in the Caroline/Sundre area were much lower than urban locations in Edmonton and Calgary. The overall average CO concentration in the Caroline/Sundre area was 0.3 ppm compared to an average concentration of 1.4 ppm for the same time period in downtown Calgary. CO values were also lower than those recorded at smaller urban locations such as Fort Saskatchewan (0.6 ppm) and Fort McMurray (0.4 ppm). Monitoring for CO is not routinely conducted at rural locations in Alberta. The major source of CO is vehicle exhaust emissions.


Carbon Monoxide - Caroline/Sundre Area
Concentration (ppm)
14
12
10
8
6
4
2
0
one-hour guideline
maximum one-hour concentration
average concentration
0.6
0.9
0.8
0.7
0.4
0.5
0.6
0.4
0.4
0.4
0.3
no data
0.4
Shell Caroline plant
Amoco battery
Rangeland tank farm
Shantz&Harmattan
Amoco South Caroline
Crammond area
Amoco North Caroline
Woodland Estates
James River Bridge
Town of Caroline
Amoco Rundle "B"
Town of Sundre
Pinnacle Resources


Carbon Monoxide - Comparison with Alberta Locations
Concentration (ppm)
14
12
10
8
6
4
2
0
one-hour guideline
maximum one-hour concentration
average concentration
0.9
4.8
5.2
1.7
1.4
1.5
Sundre/Caroline Area
Calgary Central
Calgary East
Edmonton East
Fort McMurray
Fort Saskatchewan

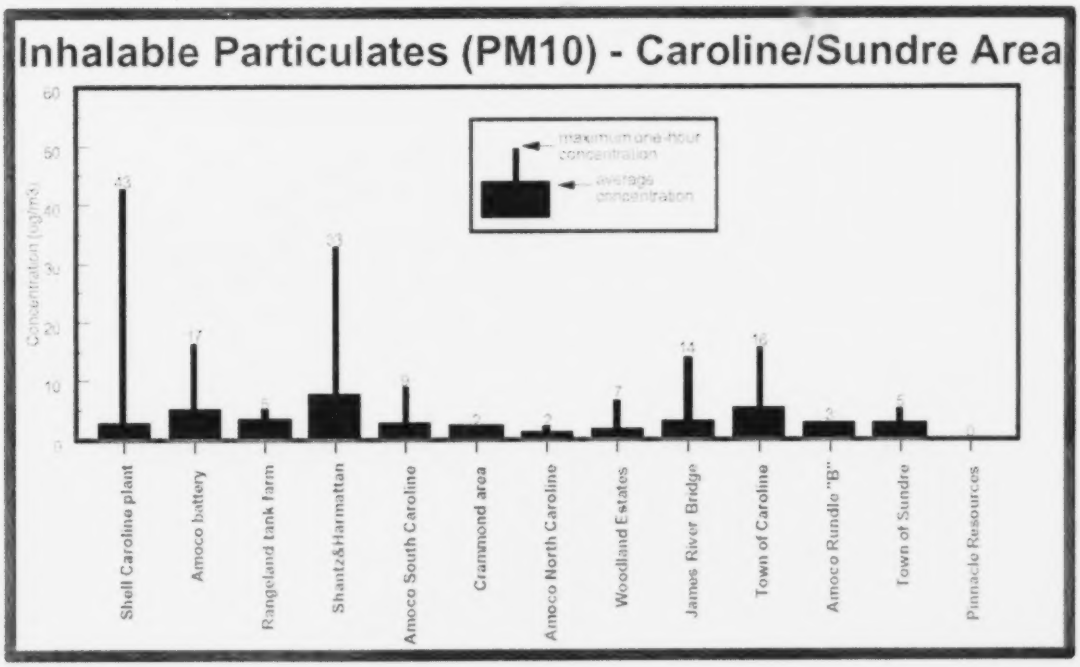
Particulates (TSP, PM_{10} and $PM_{2.5}$)

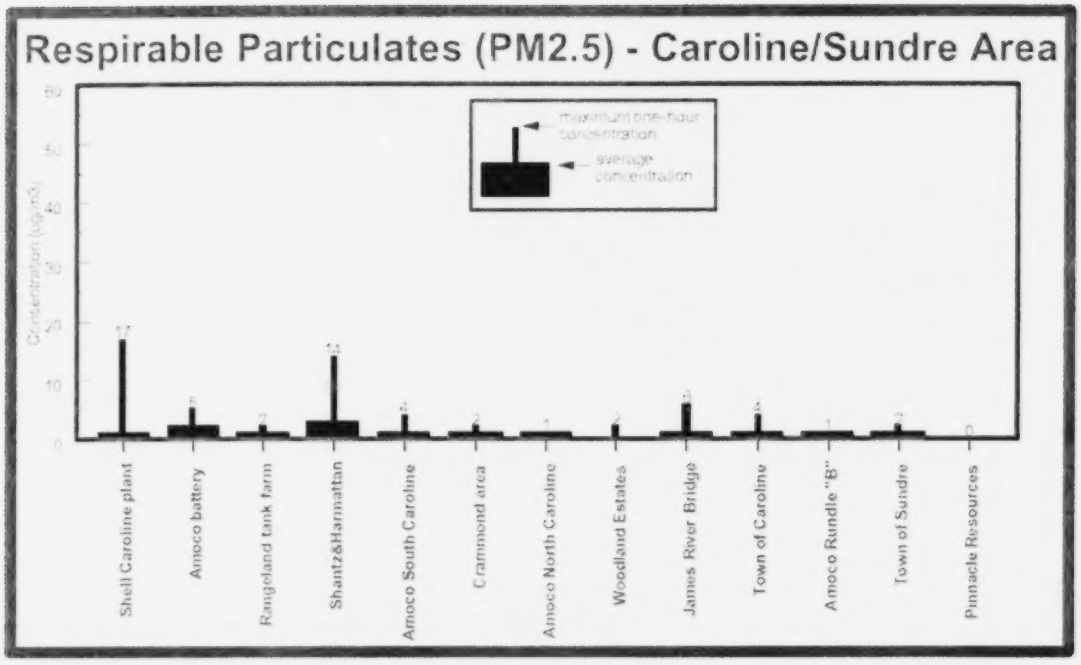
max. one-hour concentration	one-hour guideline
TSP = 52 µg/m³	no guideline
PM_{10} = 43 µg/m³	no guideline
$PM_{2.5}$ = 17 µg/m³	no guideline

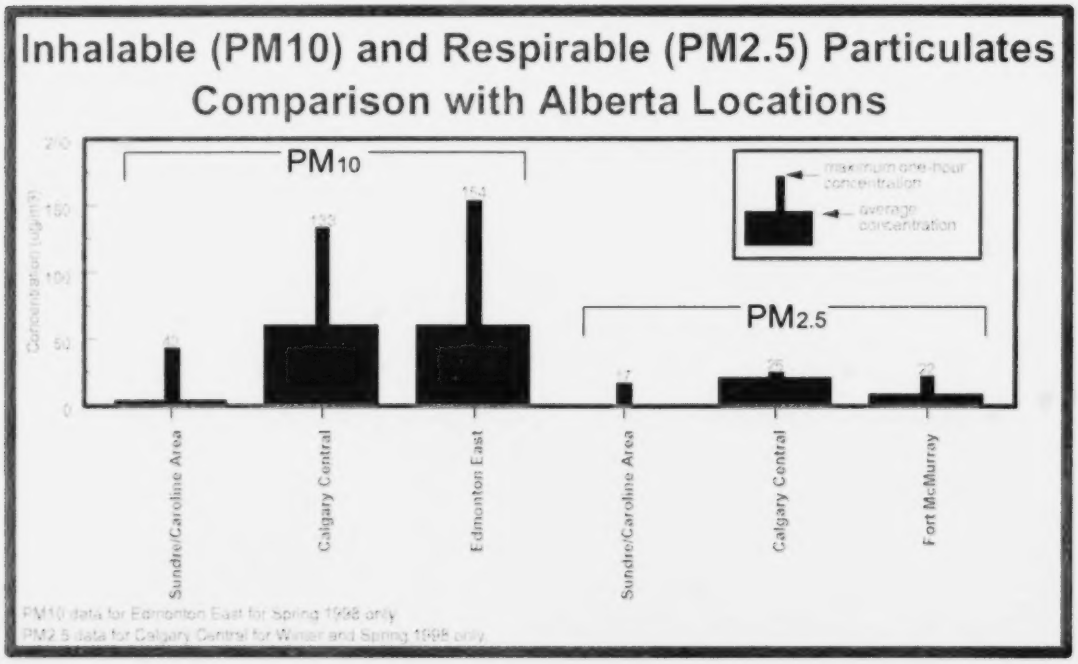
Air pollutants are not necessarily in a gaseous form. Tiny particles of solid material or liquid droplets, defined collectively as particulates are also present in the atmosphere. Total suspended particulates (TSP) refers to all particles up to 500 microns in diameter (a human hair is about 100 microns in diameter) and are important primarily from a nuisance perspective. Particles less than 10 microns in diameter (PM_{10}) can be inhaled into the nose and throat while smaller particles, less than 2.5 microns in diameter ($PM_{2.5}$), can penetrate into the lungs. Sources of particulates include soil dust, road dust, agricultural dust (e.g., harvest), smoke from forest fires and recreational wood burning, vehicle exhaust emissions, brake and tire ware, and industrial emissions. Smaller particles ($PM_{2.5}$) originate in the atmosphere because of condensation and combustion from sources such as vehicle exhaust emissions, industrial emissions and wood burning.

The highest one-hour average particulate concentrations were observed northwest of the Shell Caroline gas plant in the afternoon of October 30, 1997. These maximum values were due to traffic movement in the vicinity of the MAML. The second highest particulate concentrations were measured near the Shell Shantz and Mobile Harmattan facilities in the afternoon on April 29, 1998. One-hour average TSP, PM_{10} and $PM_{2.5}$ concentrations at this time were 48, 33 and 14 µg/m³, respectively.

Particulate concentrations in the Caroline/Sundre area were low compared to urban locations in Alberta. The overall average PM_{10} and $PM_{2.5}$ concentrations in the Caroline/Sundre area were 4 and 1 µg/m³, respectively. These values are much lower than the average PM_{10} (31 µg/m³) and $PM_{2.5}$ (20 µg/m³) concentration measured in downtown Calgary for the same time period.




Respirable Particulates (PM2.5) - Caroline/Sundre Area
maximum one-hour concentration
average concentration
Concentration (ug/m3)
0
10
20
30
40
50
60
17
5
2
14
4
2
1
2
3
4
1
2
0
Shell Caroline plant
Amoco battery
Rangeland tank farm
Shantz&Harmattan
Amoco South Caroline
Crammond area
Amoco North Caroline
Woodland Estates
James River Bridge
Town of Caroline
Amoco Rundle "B"
Town of Sundre
Pinnacle Resources


Inhalable (PM10) and Respirable (PM2.5) Particulates
Comparison with Alberta Locations
PM10
PM2.5
maximum one-hour concentration
average concentration
Concentration (ug/m3)
0
50
100
150
200
46
122
154
17
25
22
Sundre/Caroline Area
Calgary Central
Edmonton East
Sundre/Caroline Area
Calgary Central
Fort McMurray
PM10 data for Edmonton East for Spring 1998 only
PM2.5 data for Calgary Central for Winter and Spring 1998 only

Overall Average Air Quality Parameter Concentratons at Other Locations in Alberta [a]														
Location	CO (ppm)	O_3 (ppm)	NO_X (ppm)	NO_2 (ppm)	NO (ppm)	THC (ppm)	RHC (ppm)	CH_4 (ppm)	H_2S (ppm)	SO_2 (ppm)	TRS (ppm)	TSP (ug/m^3)	PM_{10} (ug/m^3)	$PM_{2.5}$ (ug/m^3)
Sundre/Caroline Area	0.3	0.039	0.018	0.012	0.008	2.1	0.2	1.8	0.000	0.003	0.000	5.8	3.9	1.5
Calgary Central [b]	1.4	0.019	0.077	0.036	0.042	2.2	no data	no data	no data	no data	no data	no data	60.0	19.7
Calgary East	1.2	0.023	0.112	0.036	0.075	2.2	no data	no data	0.001	0.004	no data	no data	no data	no data
Edmonton East [c]	0.5	0.027	0.046	0.018	0.028	2.7	no data	no data	0.001	0.003	no data	no data	60.0	no data
Fort McMurray	0.4	0.025	0.012	0.008	0.004	2.0	no data	no data	0.000	0.001	no data	no data	no data	8.7
Fort Saskatchewan	0.6	0.027	0.036	0.015	0.021	2.0	no data	no data	0.001	0.003	no data	no data	no data	no data
Tomahawk [d]	no data	0.032	no data	no data	no data	no data	no data	no data	no data	0.001	no data	no data	no data	no data
Violet Grove [d e]	no data	0.038	0.004	0.003	0.001	2.1	no data	no data	no data	0.001	no data	no data	no data	no data
High Tower Ridge [d]	no data	0.048	no data	no data	no data	no data	no data	no data	no data	no data	no data	no data	no data	no data
Shell Caroline Schmiemann [f]	no data	0.036	no data	0.007	no data	2.0	no data	1.9	0.000	0.001	no data	no data	no data	no data

a Average concentrations calculated for the the same time period as monitoring in the Caroline/Sundre area.

b Average particulate concentration only for winter and spring, 1998.

c Average particulate concentration only for spring, 1998.

d Station operated by the West Central Airshed Society.

e Total hydrocarbons is the sum of RHC and CH_4.

f Average is for only fall, 1997 and winter and spring, 1998.

List of Air Quality Parameters

CO - carbon monoxide
O_3 - ozone
NO_X - total oxides of nitrogen
NO_2 - nitrogen dioxide
NO - nitric oxide
THC - total hydrocarbons
RHC - reactive hydrocarbons
CH_4 - methane
H_2S - hydrogen sulphide
SO_2 - sulphur dioxide
TRS - total reduced sulphur
TSP - total suspended particulates
PM_{10} - inhalable particulates
$PM_{2.5}$ - respirable particulates

Weather Conditions on Mobile Monitoring Survey Days *				
Survey Day	Temperature (°C)	Predominant Wind Directions	Wind Speed (km/h)	Sky Condition (% of cloud cover)
April 22, 1997	7 to 11	east, northeast, south-southwest and west	8 to 30	30 to 80%
April 23, 1997	4 to 12	east to southeast	7 to 16	0 to 80%
July 21, 1997	20 to 30	southeast to northeast	11 to 22	0%
July 22, 1997	17 to 24	south-southwest to east	7 to 24	20 to 90%
July 23, 1997	11 to 22	southwest and east-northeast	6 to 12	0%
October 28, 1997	0 to 5	south-southeast to east-southeast	4 to 8	n/a
October 29, 1997	1 to 12	south and west to northwest	7 to 19	n/a
October 30, 1997	5 to 16	south to west	12 to 34	n/a
January 27, 1998	-6 to +6	southwest and northwest	0 to 2	10%
January 28,1998	-12 to +6	south-southeast and east-northeast	1 to 10	15 to 100%
January 29, 1998	0 to 8	south to south-southwest	2 to 15	50 to 90%
April 27, 1998	17 to 24	southeast and northwest	9 to 13	0 to 60%
April 28, 1998	11 to 24	southeast, southwest, northwest and north	7 to 20	0%
April 29, 1998	13 to 25	west, southeast and south	3 to 14	20 to 70%

* Weather conditions are based on measurements by the MAML (temperature and wind) and observations by AEP staff (sky condition) at monitoring sites.

n/a Data not available.

Overall Average Air Quality Parameter Concentrations in the Caroline/Sundre Area

Monitoring Area	CO (ppm)	O_3 (ppm)	NO_X (ppm)	NO_2 (ppm)	NO (ppm)	THC (ppm)	RHC (ppm)	CH_4 (ppm)	H_2S (ppm)	SO_2 (ppm)	TRS (ppm)	TSP (ug/m^3)	PM_{10} (ug/m^3)	$PM_{2.5}$ (ug/m^3)
Shell Caroline gas plant	0.3	0.044	0.018	0.011	0.007	2.1	0.3	1.8	0.001	0.004	0.001	4.1	2.8	1.1
Amoco battery	0.3	0.036	0.018	0.011	0.007	2.3	0.2	2.0	0.000	0.004	0.000	9.6	5.1	1.8
Amoco Rangeland tank farm	0.4	0.039	0.019	0.010	0.009	2.1	0.2	1.8	0.000	0.001	0.000	5.0	3.5	1.2
Shell Shantz/Mobil Harmattan facilities	0.4	0.040	0.023	0.014	0.009	2.1	0.2	1.8	0.001	0.003	0.001	9.5	7.6	3.1
Amoco South Caroline gas plant	0.4	0.032	0.017	0.012	0.005	2.2	0.3	1.8	0.000	0.006	0.000	5.0	3.1	1.3
Crammond area	0.5	0.028	0.041	0.028	0.013	2.1	0.3	1.8	0.000	0.002	0.000	3.1	2.4	0.8
Amoco North Caroline gas plant	0.4	0.043	0.016	0.010	0.007	2.0	0.2	1.7	0.001	0.004	0.000	2.2	1.3	0.5
Woodland Estates (McMurtry Res.)	0.3	0.031	0.013	0.011	0.002	2.5	0.4	2.0	0.000	0.001	0.000	3.3	1.9	0.4
James River Bridge Store	0.2	0.026	0.028	0.016	0.014	2.4	0.4	1.9	0.000	0.001	0.000	4.7	3.4	1.4
Town of Caroline	0.2	0.037	0.023	0.017	0.005	2.1	0.3	1.8	0.000	0.002	0.001	9.2	5.6	1.5
Amoco Rundle "B" facility	0.3	0.042	0.011	0.009	0.002	2.0	0.2	1.8	0.001	0.009	0.001	4.9	2.8	0.5
Town of Sundre	no data	0.042	0.021	0.009	0.014	2.2	0.2	1.9	0.000	0.002	0.000	4.9	3.0	1.3
Pinnacle Resources facility	0.4	0.035	0.011	0.010	0.001	2.1	0.4	1.7	0.000	0.001	0.000	0.0	0.0	0.0
overall avg. concentration	**0.3**	**0.039**	**0.018**	**0.012**	**0.008**	**2.1**	**0.2**	**1.8**	**0.000**	**0.003**	**0.000**	**5.8**	**3.9**	**1.5**

Maximum One-hour Air Quality Parameter Concentrations in the Caroline/Sundre Area

Monitoring Area	CO (ppm)	O_3 (ppm)	NO_X (ppm)	NO_2 (ppm)	NO (ppm)	THC (ppm)	RHC (ppm)	CH_4 (ppm)	H_2S (ppm)	SO_2 (ppm)	TRS (ppm)	TSP (ug/m^3)	PM_{10} (ug/m^3)	$PM_{2.5}$ (ug/m^3)
Shell Caroline gas plant	0.6	0.057	0.067	0.031	0.042	2.6	0.7	2.3	0.002	0.043	0.003	52.3	42.7	17.3
Amoco battery	0.9	0.058	0.062	0.030	0.047	2.9	0.6	2.6	0.001	0.016	0.001	25.0	16.5	5.1
Amoco Rangeland tank farm	0.8	0.055	0.041	0.023	0.020	2.1	0.4	1.9	0.001	0.002	0.001	7.3	5.1	1.6
Shell Shantz/Mobil Harmattan facilities	0.7	0.058	0.061	0.027	0.038	2.3	0.3	1.9	0.008	0.003	0.008	47.5	32.9	14.3
Amoco South Caroline gas plant	0.4	0.059	0.036	0.026	0.023	2.4	0.5	1.9	0.001	0.023	0.001	16.3	8.9	4.3
Crammond area	0.5	0.037	0.086	0.040	0.045	2.3	0.4	1.8	0.001	0.004	0.000	3.2	2.0	0.5
Amoco North Caroline gas plant	0.6	0.050	0.046	0.022	0.024	2.1	0.3	1.8	0.002	0.009	0.001	4.6	2.0	1.1
Woodland Estates (McMurtry Res.)	0.4	0.036	0.026	0.025	0.004	2.8	0.5	2.3	0.001	0.002	0.000	14.2	6.8	1.7
James River Bridge Store	0.4	0.057	0.036	0.022	0.043	2.6	0.7	2.0	0.001	0.005	0.001	19.8	14.1	5.9
Town of Caroline	0.4	0.044	0.048	0.032	0.016	2.2	0.4	1.8	0.000	0.005	0.001	26.2	15.6	4.2
Amoco Rundle "B" facility	0.3	0.042	0.011	0.009	0.002	2.0	0.2	1.8	0.001	0.009	0.001	4.9	2.8	0.5
Town of Sundre	no data	0.055	0.022	0.009	0.016	2.5	0.4	1.9	0.000	0.003	0.000	6.5	5.2	2.4
Pinnacle Resources facility	0.4	0.035	0.011	0.010	0.001	2.1	0.4	1.7	0.000	0.001	0.000	0.0	0.0	0.0
max. one-hour concentration	**0.9**	**0.059**	**0.086**	**0.040**	**0.047**	**2.9**	**0.7**	**2.6**	**0.008**	**0.043**	**0.008**	**52.3**	**42.7**	**17.3**

Peak Five-minute Air Quality Parameter Concentrations in the Caroline/Sundre Area

Monitoring Area	CO (ppm)	O_3 (ppm)	NO_X (ppm)	NO_2 (ppm)	NO (ppm)	THC (ppm)	RHC (ppm)	CH_4 (ppm)	H_2S (ppm)	SO_2 (ppm)	TRS (ppm)	TSP (ug/m^3)	PM_{10} (ug/m^3)	$PM_{2.5}$ (ug/m^3)
Shell Caroline gas plant	3.5	0.059	0.117	0.108	0.081	4.4	1.5	2.8	0.004	0.058	0.008	91.2	75.0	30.4
Amoco battery	1.1	0.058	0.109	0.032	0.086	3.5	1.3	3.4	0.002	0.055	0.002	147.8	92.4	27.4
Amoco Rangeland tank farm	1.4	0.057	0.100	0.050	0.068	3.2	1.2	2.0	0.002	0.003	0.002	25.4	17.6	8.0
Shell Shantz/Mobil Harmattan facilities	1.5	0.059	0.160	0.053	0.125	2.6	0.6	2.1	0.011	0.030	0.010	186.8	128.0	57.0
Amoco South Caroline gas plant	3.8	0.059	0.041	0.038	0.028	3.0	1.0	2.3	0.002	0.122	0.002	80.8	38.6	15.0
Crammond area	0.7	0.043	0.110	0.046	0.065	2.3	0.5	1.9	0.001	0.004	0.001	9.0	8.4	3.2
Amoco North Caroline gas plant	0.8	0.050	0.098	0.035	0.063	2.3	0.6	1.9	0.002	0.028	0.001	31.2	16.2	4.0
Woodland Estates (McMurtry Res.)	0.5	0.038	0.027	0.025	0.005	4.2	1.0	3.8	0.001	0.002	0.001	27.8	13.2	3.4
James River Bridge Store	0.9	0.059	0.039	0.026	0.085	2.9	1.0	2.1	0.001	0.005	0.001	55.4	41.0	16.2
Town of Caroline	0.5	0.044	0.108	0.053	0.054	2.6	0.6	2.0	0.001	0.008	0.001	92.4	56.4	15.4
Amoco Rundle "B" facility	0.6	0.044	0.029	0.025	0.007	2.1	0.3	1.8	0.003	0.023	0.002	29.0	14.8	3.4
Town of Sundre	no data	0.055	0.097	0.050	0.047	3.2	1.2	2.0	0.001	0.003	0.001	25.4	17.6	8.0
Pinnacle Resources facility	0.4	0.043	0.012	0.011	0.001	2.0	0.3	1.6	0.000	0.001	0.000	0.0	0.0	0.0
peak five-min. concentration	**3.8**	**0.059**	**0.160**	**0.108**	**0.125**	**4.4**	**1.5**	**3.8**	**0.011**	**0.122**	**0.010**	**186.8**	**128.0**	**57.0**

List of Air Quality Parameters

CO - carbon monoxide
O_3 - ozone
NO_X - total oxides of nitrogen
THC - total hydrocarbons
RHC - reactive hydrocarbons
CH_4 - methane
TRS - total reduced sulphur
TSP - total suspended particulates
PM_{10} - inhalable particulates

Part 2: Monitoring Using Passive Techniques

Passive methods provide a cost-effective solution for monitoring air quality at locations where continuous monitoring is not practical. The advantages of using passive air quality monitoring methods are that:

- there is no need for power, data loggers or pumps; and
- the passive samplers are relatively easy to install because of their lightweight and portability.

Some disadvantages of passive methods are that:

- samples must be sent to a laboratory for analysis and therefore the results are not immediately available; and
- samples are usually collected over a longer period of time (24 hours to one month) and therefore events that last for short periods of time may be "averaged out" depending on the monitoring time period.

Passive samplers work by the physical process of diffusion. No active movement of air through the sampler is necessary. Air pollutants diffuse through a membrane, and collect on a filter that has been specifically coated to absorb the pollutant of interest. The entire assembly is sent to a laboratory to be analyzed for the amount of pollutant on the filter. From this value, the average ambient concentration of the pollutant can be calculated.

Passive samplers were used to monitor monthly concentrations of sulphur dioxide (SO_2) and odour triggered samples of volatile organic compounds (VOCs) in the Caroline/Sundre area. This sampling took place from late October 1997 to the end of April 1998. Prior to discussing the passive monitoring results, meteorological data for the six-month monitoring period is presented.

Meteorological Data

Meteorological factors, such as temperature, humidity and wind speed, are important when calculating ambient SO_2 concentrations from passive samplers. These factors will effect the sampling rate of SO_2 on to collection media of the passive sampler. Meteorological factors will also effect the sampling rate for VOCs onto the passive samplers. However, only ambient temperature is taken into account when calculating the sampling rate from the passive VOC samplers. Weather information, such as wind direction, is also important in assessing the general transport of pollutants in the Caroline/Sundre area during the six-month monitoring period.

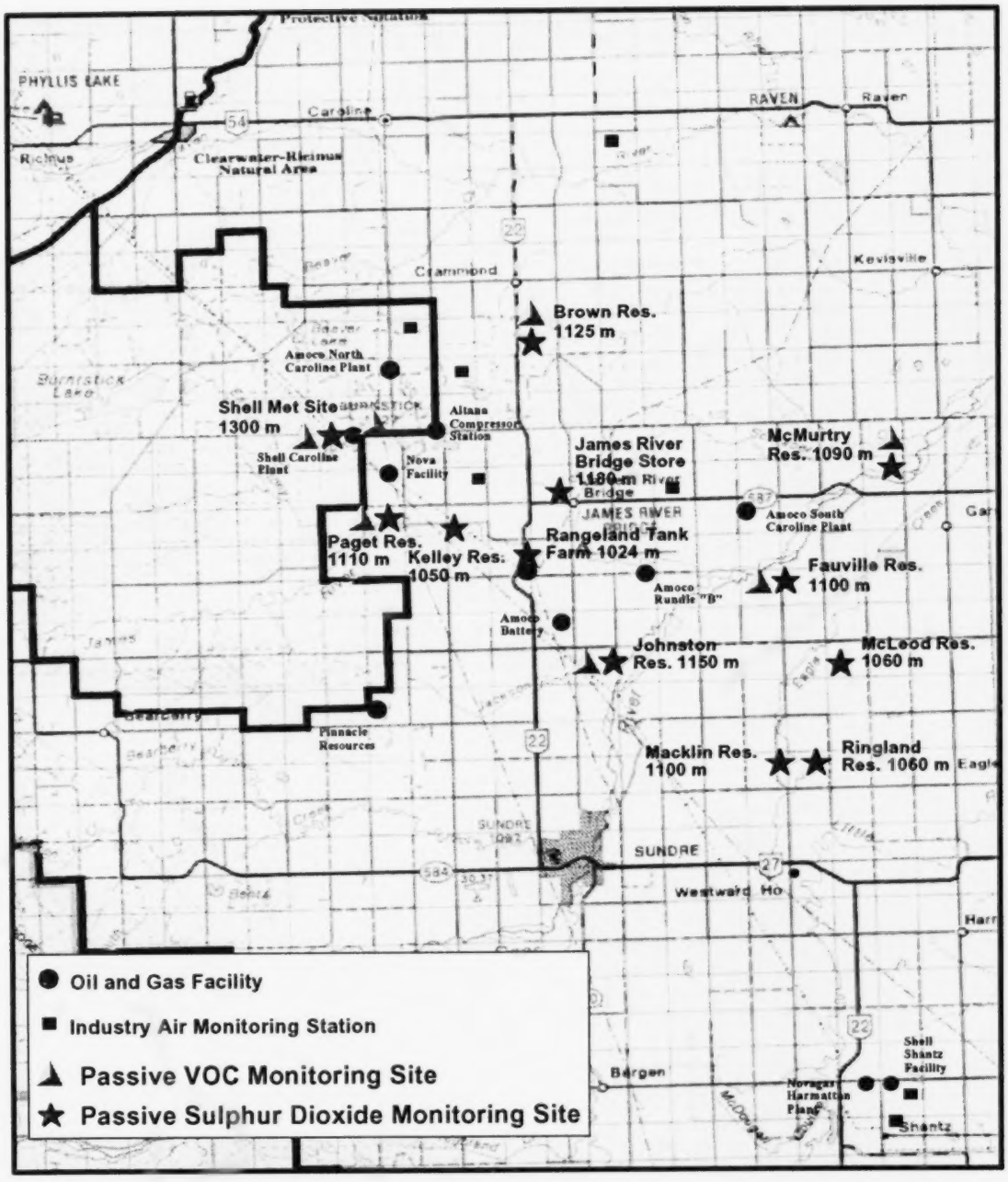
Winds were pre-dominantly from the southwest to west directions in November, December and February based on data from the Environment Canada meteorological station located near Sundre. In January winds had a west component 25% of the time and a northeast component 21% of the time. The pre-dominant wind directions in March were from the east to southeast and from the west to southwest directions. In April, winds had a west component 25% of the time and a southeast component 25% of the time. Calm winds were reported from 6% of the time in April to 18% of the time in January. Average monthly wind speeds ranged from 4.2 km/h in January to 7.7 km/h in December and April during this six-month monitoring period.

Ambient temperatures were relatively mild in November, December, February and March with monthly average values between –6 and –3 °C. Much cooler temperatures were recorded in January with an average value of –16.7 °C. The monthly average temperature at the Sundre weather station in April was 4.7 °C. Monthly average relative humidity values ranged from about 55% in December to 78% in March.

Weather Conditions During Passive Monitoring Period *

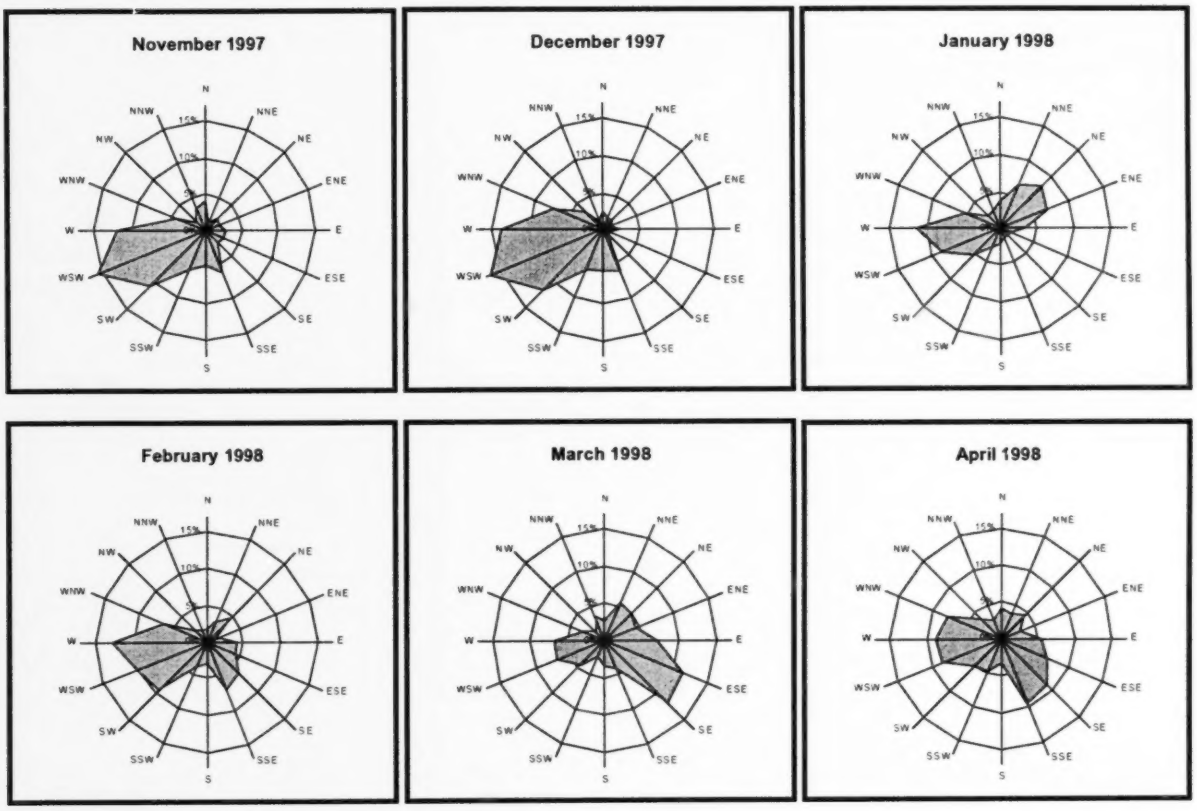
Month	Predominant Wind Directions	Average Wind Speed (km/h)	Average Temperature (°C)	Average Relative Humidity (%)
November	southwest to west (38%)	5.9	-3.3	71.7
December	southwest to west (42%)	7.7	-4.3	54.6
January	west (25%) and northeast (21%)	4.2	-16.7	74.4
February	southwest to west (32%)	5.3	-5.9	72.6
March	east to southeast (30%) and west to southwest (18%)	7.4	-4.7	77.9
April	west (25%) and southeast (25%)	7.7	4.7	67.2

* Weather data is from the Environment Canada Sundre weather station.



Caroline/Sundre Area Passive Monitoring Sites

Wind Direction Frequency Distribution
November 1997 to April 1998



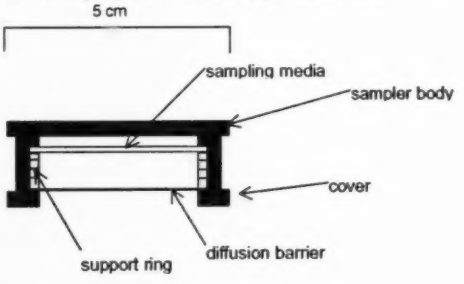
Passive Monitoring for Sulphur Dioxide (SO_2)

SO_2 was monitored on a monthly basis by passive samplers at 12 locations in the Caroline/Sundre area. A total of 72 samples were collected over a six-month period from November 1997 to and April 1998, inclusive. Passive SO_2 data were used primarily to determine: (1) the general spatial variation of SO_2 in the area; and (2) the variation of SO_2 concentration with elevation in the Caroline/Sundre area.

As mentioned earlier in this report, SO_2 is a colourless gas with a pungent odour. In Alberta, the major sources of SO_2 are natural gas processing plants, oil sands facilities, and power plants. Other sources include gas plant flares, oil refineries, pulp and paper mills and fertilizer plants.

Monitoring Method

The passive sampler used for monitoring SO_2 in the Caroline/Sundre area was the *All Season SO_2 Passive Sampler* developed by Maxxam Analytics. The sampler consists of a polycarbonate body, about five



All Season SO_2 Passive Sampler

centimeters in diameter. The sampling media and a support ring are enclosed in the body. In order to reduce interference by particulate matter and condensation, the sampler was designed to be installed facedown in a rain shelter. The diffusion barrier is a Teflon film resembling a piece of lightweight paper that is held in place across the face of the sampler by a plastic ring (labeled cover).

A one-year evaluation of this sampler was conducted by Alberta Environment from May 1997 to April 1998. The purpose of this evaluation was to determine if the passive SO2 sampler would yield concentrations comparable to continuous monitoring methods routinely used by Alberta Environment. The evaluation was conducted by placing duplicate passive SO2 samplers at Alberta Environment continuous monitoring stations located in Edmonton, Calgary, Fort Saskatchewan and Fort McMurray. The results of the evaluation showed that the passive sampler was reliable for determining monthly SO2 concentrations within 12% of the monthly concentrations from continuous monitors. Duplicate passive SO2 sampling results showed that the SO2 passive samplers were reproducible within about 6% with a detection limit of 0.1 ppb (parts per billion). Passive SO2 concentrations were calculated using an empirical formula that takes into account the effects of temperature, humidity and wind speed.

Results

Average SO2 concentrations in the Caroline/Sundre area for the six-month monitoring period ranged from 2.1 ppb at the Kelley residence (7 km southeast of the Shell Caroline gas plant) to 3.4 ppb at the Shell meteorological tower (1 km west of the Shell Caroline gas plant). A ppb (part per billion) is equal to a ppm (part per million) times 1000. The second highest six-month average SO2 concentration was measured at the Rangeland tank farm (12 km north of Sundre) and the Brown Residence (8 km northeast of the Shell Caroline gas plant). Six-month average values of 3.0 ppb were recorded at both of these locations. The six-month average SO2 concentration at all monitoring locations was below the annual guideline for SO2 of 10 ppb.

The highest monthly SO2 concentration of 6.6 ppb was recorded at the Shell meteorological tower in March followed by a value of 5.7 ppb measured in January at the Rangeland tank farm. Monthly maximum values higher than 5 ppb were also recorded at the Johnston Residence (8 km north of Sundre) in March (5.6 ppb), Fauville Residence (14 km northeast of Sundre) in March (5.6 ppb), and Macklin Residence (9 km east-northeast of Sundre) in January (5.2 ppb). Monthly SO2 concentrations were below Alberta's annual guideline of 10 ppb at all locations. Alberta does not have a monthly air quality guideline for SO2.

Ambient SO2 concentrations were highest in either January or March at all monitoring locations. Average monthly SO2 values for all 12 monitoring sites in January and March were 4.8 and 4.0 ppb, respectively. Average SO2 concentrations ranged from 1.3 to 2.8 ppb during the remaining months. Total SO2 emissions (including incinerators and flares) from the major gas plants in the area were highest in March (567 tonnes) and third highest in January (498 tonnes). Flaring from the Shell Caroline gas plant in March was unusually high at 104 tonnes compared to 15 to 66 tonnes in the remaining months during the six-month monitoring period. The second highest total SO2 emissions occurred in April (530 tonnes) when ambient SO2 concentrations from the passive samplers were relatively low (1.5 ppb). Lower ambient SO2 values in April were likely due to better dispersion conditions with stronger wind speeds and a generally lower frequency of temperature inversions.

SO2 concentrations from passive samplers did not show a defined relationship with elevation during the monitoring period. The highest concentrations were generally recorded closer to industrial facilities in the region such as the Shell Caroline gas plant and Rangeland tank farm. However, on average, lower SO2 concentrations were measured in the James River valley near the Paget and Kelley residences.

SO2 concentrations over the six-month period were lower in the Caroline/Sundre area (2.6 ppb) than at urban locations such as the Edmonton East (4.1 ppb) and Calgary East (2.9 ppb) monitoring stations. However, the average SO2 concentration for the six-month monitoring period was higher in the Caroline/Sundre area than at the WCAS Violet Grove (1.6 ppb) and Tomahawk (1.5 ppb) stations.

Monthly Sulphur Dioxide Concentrations from Passive Samplers (ppb)							
Monitoring Location (elevation)	November	December	January	February	March	April	Six-month Average *
Shell Met. Tower (1300 m)	1.6	1.5	5.2	3.6	6.6	1.9	**3.4**
Brown Res. (1125 m)	2.0	2.2	4.7	3.3	3.5	2.1	**3.0**
Paget Res. (1110 m)	0.8	0.7	4.8	2.1	5.2	1.6	**2.5**
Kelley Res. (1050 m)	0.5	0.6	4.4	2.2	3.4	1.1	**2.1**
Rangeland Tank Farm (1025 m)	1.8	1.5	5.7	3.3	3.6	1.8	**3.0**
Johnston Res. (1150 m)	0.8	0.8	4.9	2.2	5.6	1.3	**2.6**
James River Bridge (1180 m)	1.4	1.5	5.0	2.7	3.6	1.6	**2.6**
McMurtry Res. (1090 m)	1.0	1.6	3.7	2.6	3.1	1.3	**2.2**
Fauville Res. (1100 m)	1.2	1.3	4.2	2.5	5.6	1.4	**2.7**
McLeod Res. (1060 m)	1.4	1.2	4.8	2.9	2.5	1.4	**2.4**
Ringland Pasture (1060 m)	1.8	1.2	4.9	3.7	1.8	1.6	**2.5**
Macklin Res. (1100 m)	1.3	1.1	5.2	2.3	3.4	1.2	**2.4**

* Annual guideline for sulphur dioxide is 10 ppb.

Comparison of Sulphur Dioxide Concentrations in the Caroline/Sundre Area with Other Locations (ppb)							
Monitoring Location [a]	November	December	January	February	March	April	Six-month Average *
Caroline/Sundre Area	1.3	1.3	4.8	2.8	4.0	1.5	**2.6**
Edmonton East	3.2	3.5	3.4	3.3	1.9	1.8	**2.9**
Calgary East	4.1	3.6	6.6	4.0	3.6	2.8	**4.1**
Fort Saskatchewan	2.1	2.5	3.5	2.8	1.9	1.4	**2.4**
Fort McMurray	0.8	0.4	1.1	1.2	1.4	0.6	**0.9**
Violet Grove [b]	1.5	1.3	2.4	2.1	1.1	1.0	**1.6**
Tomahawk [c]	1.4	1.0	2.3	2.5	1.1	0.8	**1.5**

* Annual guideline for sulphur dioxide is 10 ppb.

a Data for other locations is from continuous air quality monitoring instruments.

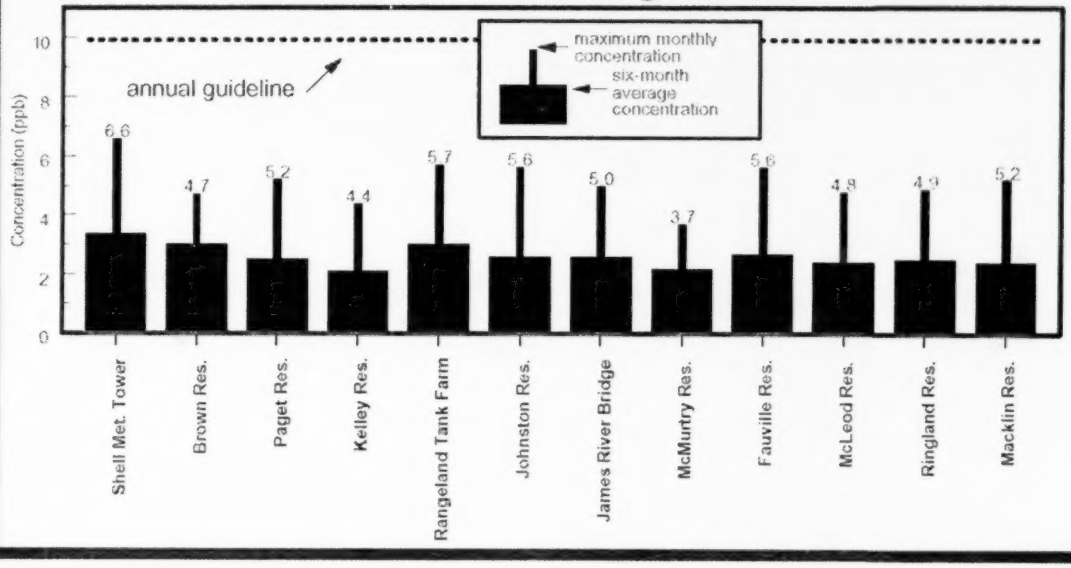
b Located 10 km southwest of Drayton Valley.

c Located 25 km northeast of Drayton Valley.

Sulphur Dioxide Emissions from Major Gas Plants in the Caroline/Sundre Area (tonnes)							
Gas Plant	November	December	January	February	March	April	Six-month Total
Shell Caroline (Incinerator)	238	315	301	243	300	319	**1715**
Shell Caroline (Flaring)	28	15	46	25	104	66	**283**
Novagas Harmattan (Incinerator)	54	55	56	53	57	52	**327**
Novagas Harmattan (Flaring)	0	0	0	0	0	3	**3**
Amoco South Caroline (Incinerator)	53	52	52	50	56	49	**312**
Amoco South Caroline (Flaring)	0	0	0	0	0	0	**0**
Amoco North Caroline (Incinerator)	44	47	43	39	50	42	**264**
Amoco North Caroline (Flaring)	0	1	0	0	0	0	**1**
Total (Incinerator)	389	469	451	385	463	461	**2618**
Total (Flaring)	28	16	47	25	104	69	**288**
Total (Incinerator and Flaring)	417	485	498	410	567	530	**2906**

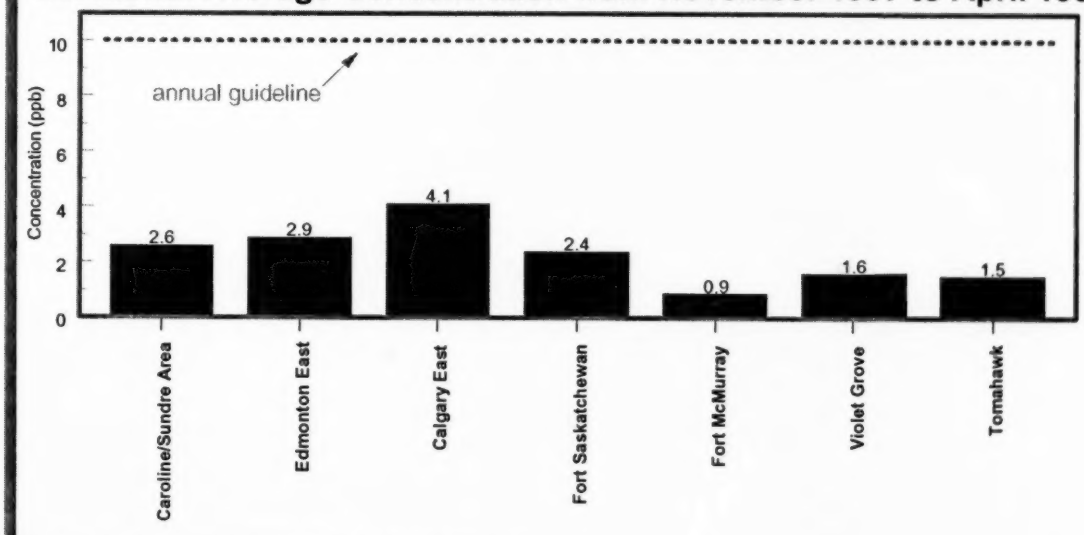
Sulphur Dioxide in the Caroline/Sundre Area

Passive Monitoring Results



Sulphur Dioxide - Comparison with Alberta Locations

Six-month Average Concentration from November 1997 to April 1998



Data for other locations is from continuous monitoring instruments.

Passive Monitoring for Volatile Organic Compounds (VOCs)

A total of 29 VOC samples were collected at seven locations in the Caroline/Sundre area between October 1997 and April 1998. Most of these samples were collected for a 6 to 36 hour time period based on odours or other air quality concerns identified by local residents. These samples were analyzed for benzene, toluene, ethylbenzene and xylenes, often referred to as BTEX.

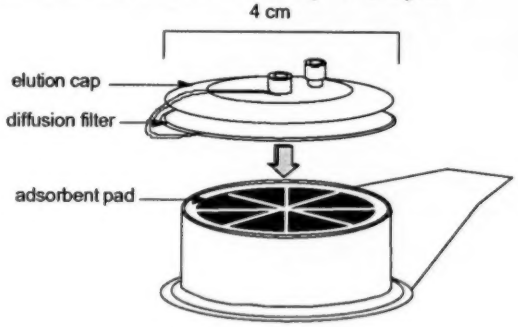
The major sources of VOCs in the outdoor environment are automobile emissions, gasoline marketing and storage tanks, petroleum and chemical industries, and natural gas combustion. Individual VOCs are also produced from the evaporation of solvents and organic chemicals as well as from leaking valves, flanges, pumps and compressors at industrial facilities. VOCs are also contained in incinerator and flare stack emissions associated with the oil and gas industry. Organic compounds such as benzene are also emitted by many indoor sources such as cigarette smoke.

Benzene is a known cancer causing substance if exposed to high concentrations for a prolonged period of time. Benzene is recognized as a chemical "concluded to be toxic" on the Environment Canada First Priority Substances List (PSL1) (Environment Canada, 1995). The Alberta interim air quality guideline for benzene is 30 $\mu g/m^3$ (micrograms of benzene per cubic meter of air) as a one-hour average concentration. Benzene can be detected as an odour at concentrations of about 4500 $\mu g/m^3$ (Ruth, 1986). Benzene is also ranked fifth on the U.S. Department of Health and Human Services Agency for Toxic Substances and Disease Registry (ATSDR) list of hazardous substances.

Toluene and xylenes are recognized as chemicals "not concluded to be toxic" on the PSL1 list. The toxicity of ethylbenzene is being considered on the Environment Canada Second Priority Substances List (PSL2). However, toluene, ethylbenzene and xylenes are ranked 55th, 80th and 83rd, respectively, on the ATSDR list of hazardous substances. Alberta does not have air quality guidelines for toluene, ethylbenzene and xylenes at the present time. Air quality point impingement standards for toluene and xylenes in Ontario are 2000 and 2300 $\mu g/m^3$, respectively, as a 24-hour concentration. The Ontario point impingement standard for ethylbenzene is 4000 $\mu g/m^3$ as a one-hour concentration. Odour thresholds for toluene, ethylbenzene and xylenes are 8025, 8700 and 348 $\mu g/m^3$, respectively (Ruth, 1986).

Monitoring Method

The VOC sampler used in this study was the *Organic Vapor Monitor 3500* passive sampling device developed by 3M. The monitor consists of a circular base, about four centimeters in diameter, that contains a charcoal like substance as the adsorbent media. While sampling in the field, the diffusion filter is placed over top of the adsorbent pad. The diffusion filter is a thin white film surrounded by a plastic ring. After sampling is complete, the diffusion filter is discarded and the elution cap is placed over the adsorbent pad to avoid contamination of the sample. The sample is sealed into the original container and sent to a laboratory for analysis.



Organic Vapor Monitor 3500

The 3M Organic Vapor Monitor (OVM) was originally designed to be used as a personal exposure monitor for occupational safety applications. However, in recent years the sampler has been evaluated for use in the outdoor environment. Based on laboratory exposure chamber and field tests conducted by Gagner (1996), the 3M OVM was shown to be reliable for measuring outdoor concentrations of benzene and toluene with an accuracy of ±25%. These results are based on a comparison of VOC concentrations as measured by the 3M OVM passive sampler against the SUMMA canister active sampler used as the reference method. However, the same study cautions that the 3M OVM has a tendency to overestimate VOC levels at low concentrations, such as those that are normally observed in the ambient environment.

Results

Based on 29 samples collected at seven locations in the Caroline/Sundre area, maximum concentrations of BTEX chemicals were below interim air quality guidelines and point impingement standards established in Alberta and Ontario, respectively. Concentrations of benzene, toluene, ethylbenzene and xylenes were also

below their respective odour thresholds. However, BTEX concentrations higher than what is normally observed in the ambient environment were detected in some of the samples collected in the Caroline/Sundre area.

The highest concentration of BTEX chemicals was recorded in a sample collected at the Johnston residence (8 km north of Sundre) from 6:15 p.m. on March 17 to 6:50 a.m. on March 19. The benzene concentration in this sample (14.6 $\mu g/m^3$) was lower than the Alberta one-hour interim guideline of 30 $\mu g/m^3$. Toluene (70.9 $\mu g/m^3$), ethylbenzene (6.7 $\mu g/m^3$) and xylene (22.7 $\mu g/m^3$) levels in this sample were below Ontario's point impingement standards of 2000, 4000 and 2300 $\mu g/m^3$, respectively. These elevated BTEX values may have been associated with a well test that was reported upwind from the monitoring location during this time period.

An elevated benzene concentration was also recorded at the Johnson residence in a sample collected from 2:30 p.m. on April 17 to 8:30 a.m. on April 18. Flaring from a near-by well was noted during this time period. The benzene concentration measured in this sample (8.6 $\mu g/m^3$) was lower than the one-hour interim guideline for benzene of 30 $\mu g/m^3$. Toluene, ethylbenzene and xylene concentrations in this sample were very low compared to Ontario's point impingement standards.

The highest benzene concentration was actually measured in a background sample taken at the Fauville residence (14 km northeast of Sundre) from 11 a.m. on March 11 to 11 a.m. on March 12. The benzene concentration in this sample was 19.2 $\mu g/m^3$. This value is lower than Alberta's interim air quality guideline of 30 $\mu g/m^3$. No unusual odours or other air quality concerns were observed during the time this sample was taken. It is suspected that this sample may have been contaminated prior to being placed in the field.

An elevated toluene value was measured in a sample collected at the McMurtry residence (about 20 km northwest of Sundre) from 3:30 p.m. on January 30 to 7:30 a.m. on January 31. Again, no unusual air quality concerns were noted during this time period. The toluene concentration measured in this sample was 30.7 $\mu g/m^3$ which is much lower than the Ontario point impingement standard for 24-hour concentrations of toluene of 2000 $\mu g/m^3$.

The median benzene concentration for all 29 samples collected in the Caroline/Sundre area was 1.2 $\mu g/m^3$. This median value is lower than typical median benzene levels recorded at other locations in Alberta. Median benzene concentrations at the Edmonton Central, Edmonton East and Calgary Central monitoring stations were 2.7, 2.0 and 2.9 $\mu g/m^3$, respectively, based on data from 1991 to 1997. However, the median toluene concentration in the Caroline/Sundre area (2.6 $\mu g/m^3$) was higher than typical median values recorded at the Edmonton Central (1.3 $\mu g/m^3$), Edmonton East (0.7 $\mu g/m^3$) and Calgary Central (1.2 $\mu g/m^3$) monitoring stations. Ethylbenzene and xylene concentrations were much lower in the Caroline/Sundre area than at monitoring stations located in Edmonton and Calgary. BTEX data collected at Alberta stations is based on active sampling using the SUMMA canister monitoring method.

References

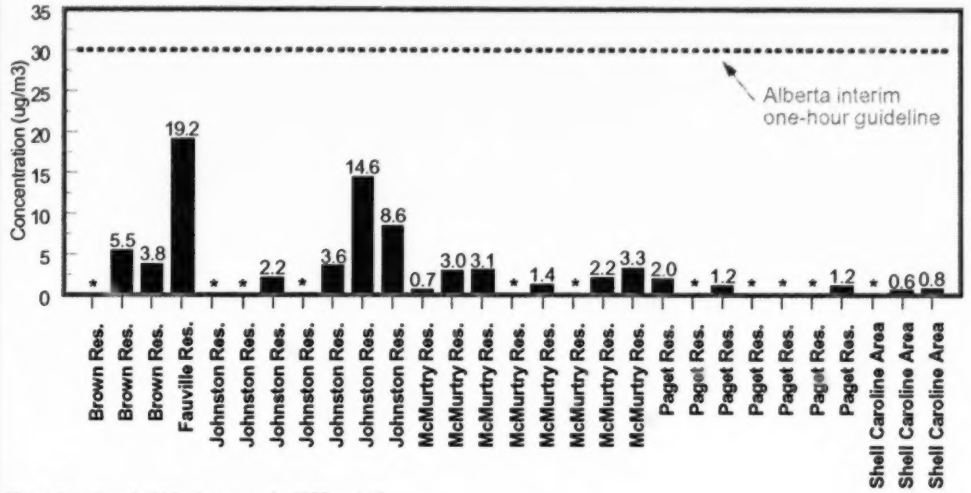
Environment Canada. 1995. Report of the Ministers' Expert Advisory Panel on the second priority substances list under the Canadian Environmental Protection Act (CEPA). PSL2 Secretariat, Environment Canada, Hull, Quebec.

Gagner, V.R. 1996. Validation of a Passive Air Sampling Device for Measuring Ambient VOCs at Subzero Temperatures. Medical Sciences, Department of Health Sciences, University of Alberta.

Ruth, J.H. 1986. Odor thresholds and irritation levels of several chemical substances: a review. Am. Ind. Hyg. Assoc. J 47: pp. A-142 to A-151.

Benzene - Caroline/Sundre Area

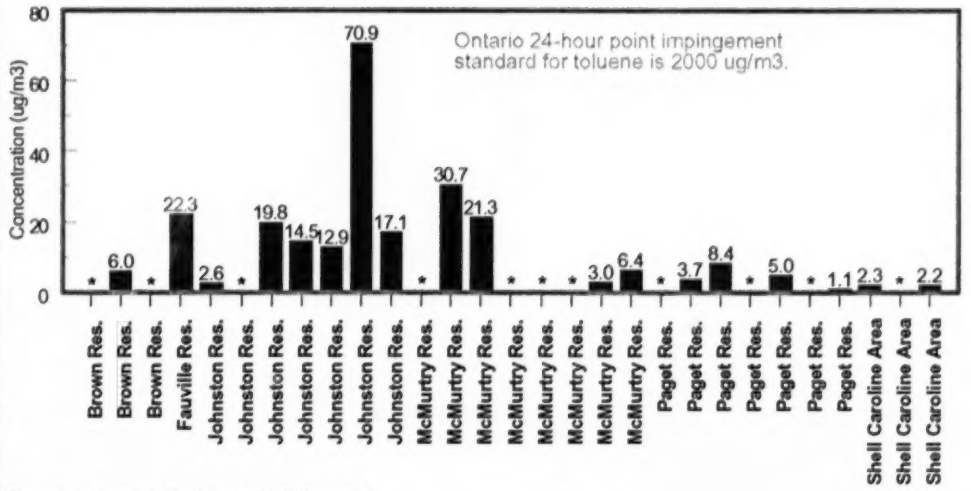
Passive Monitoring Results



The odour threshold for benzene is 4500 ug/m3.
See table on following page for monitoring dates and times at each location.
* Below analytical detection limit.

Toluene - Caroline/Sundre Area

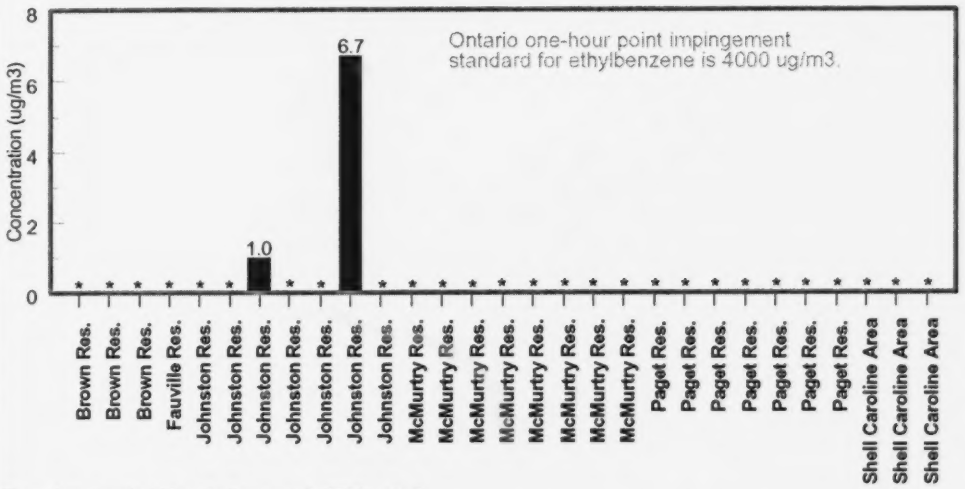
Passive Monitoring Results



The odour threshold for toluene is 8025 ug/m3.
See table on following page for monitoring dates and times at each location.
* Below analytical detection limit.

Ethylbenzene - Caroline/Sundre Area

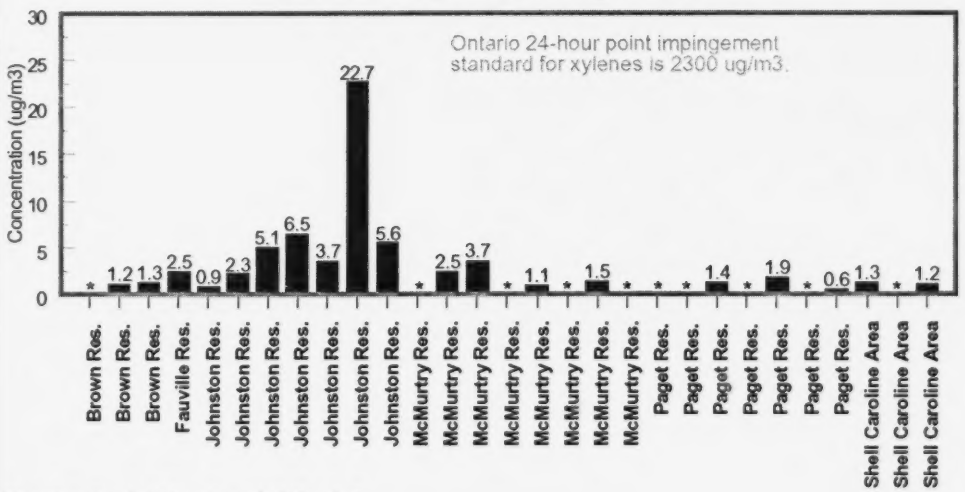
Passive Monitoring Results



The odour threshold for ethylbenzene is 8700 ug/m3.
See table on following page for monitoring dates and times at each location.
* Below analytical detection limit.

Xylenes - Caroline/Sundre Area

Passive Monitoring Results



The odour threshold for xylenes is 348 ug/m3.
See table on following page for monitoring dates and times at each location.
* Below analytical detection limit.

Volatile Organic Compound Concentrations (ug/m^3) in the Caroline/Sundre Area

Location	Installed	Removed	Duration	Comments	Benzene	Toluene	Ethylbenzene	Xylenes
Brown Res.	Feb 3'98 @ 1200	Feb 4 @ 1250	24 Hrs. 50 Min.	Background (no odours)	BDL	BDL	BDL	BDL
Brown Res.	Feb 19'98 @ 1045	Feb 20 @ 1030	23 Hrs. 45 Min.	Brief Hydrocarbon odour that disappeared by the time sampler was set out.	5.5	6	BDL	1.2
Brown Res.	Mar 30'98 @ 1030	Mar 31 @ 1800	33 Hrs. 30 Min.	Background (no odours)	3.8	BDL	BDL	1.3
Fauville Res.	Mar 11'98 @ 1100	Mar 12 @ 1100	24 Hrs.	Background (no odours)	19.2	22.3	BDL	2.5
Johnston Res.	Oct 29'97 @ 0918	Oct 30 @ 1622	31 Hrs. 4 Min.	Near Johnson Res.	BDL	2.6	BDL	0.9
Johnston Res.	Feb 19'98 @ 1530	Feb 20 @ 1545	24 Hrs. 15 Min.	Background (no odours) S.W. wind and + 7 deg.C.	BDL	BDL	BDL	2.3
Johnston Res.	Mar 6'98 @ 1100	Mar 7 @ 1033	23 Hrs. 27 Min.	Heavy smog, no odour. N.W. winds.	2.2	19.8	1.0	5.1
Johnston Res.	Mar 11'98 @ 1045	Mar 11 @ 1500	4 Hrs. 15 Min.	Canadian 88 flaring.	BDL	14.5	BDL	6.5
Johnston Res.	Mar 11'98 @ 1045	Mar 12 @ 1045	24 Hrs.	Light N.W. to S.W. winds.	3.6	12.9	BDL	3.7
Johnston Res.	Mar 17'98 @ 1815	Mar 19 @ 0650	30 Hrs. 35 Min.	Newport testing their well. Wind Coming directly from their stack.	14.6	70.9	6.7	22.7
Johnston Res.	Apr 17'98 @ 1430	Apr 18 @ 0830	18 Hrs.	Orion and Amoco flaring.	8.6	17.1	BDL	5.6
McMurtry Res.	Oct 29'97 @ 1030	Oct 30 @ 1818	32 Hrs. 48 Min.	No comments.	0.7	BDL	BDL	BDL
McMurtry Res.	Jan 30'98 @ 1550	Jan 31 @ 0730	15 Hrs. 20 Min.	No comments.	3	30.7	BDL	2.5
McMurtry Res.	Jan 30'98 @ 1550	Jan 31 @ 1615	24 Hrs. 24 Min.	W.D.=S.W. Diesel odour.	3.1	21.3	BDL	3.7
McMurtry Res.	Feb 19'98 @ 1310	Feb 19 @ 1510	2 Hrs. 10 Min.	No comments.	BDL	BDL	BDL	BDL
McMurtry Res.	Feb 19'98 @ 1310	Feb 20 @ 1330	24 Hrs. 20 Min.	Light S.W. wind (Chinook).	1.4	BDL	BDL	1.1
McMurtry Res.	Mar 11'98 @ 1330	Mar 11 @ 1630	3 Hrs.	S.W. wind. Neighbor said.	BDL	BDL	BDL	BDL
McMurtry Res.	Mar 11'98 @ 1330	Mar 12 @ 1335	24 Hrs. 5 Min.	Canadian 88 is flaring. After sample was put out the wind switched to N.E. Left out until wind switched back and for 1 more hr.	2.2	3	BDL	1.5
McMurtry Res.	Apr 24'98 @ 1200	Apr 25 @ 1345	25 Hrs. 45 Min.	Some odours.	3.3	6.4	BDL	BDL
Paget Res.	Feb 19'98 @ 1330	Feb 20 @ 1245	23 Hrs. 15 Min.	Background (no odours)	2	BDL	BDL	BDL
Paget Res.	Mar 10'98 @ 1125	Mar 10 @ 1920	7 Hrs. 20 Min.	No comments.	BDL	3.7	BDL	BDL
Paget Res.	Mar 10'98 @ 1125	Mar 11 @ 1300	25 Hrs. 35 Min.	Brief odour from west to south.	1.2	8.4	BDL	1.4
Paget Res.	Apr 4'98 @ 0945	Apr 4 @ 1945	10 Hrs.	North wind.	BDL	BDL	BDL	BDL
Paget Res.	Apr 4'98 @ 0945	Apr 5 @ 0945	24 Hrs.	No comments.	BDL	5	BDL	1.9
Paget Res.	Apr 8'98 @ 0930	Apr 9 @ 0830	24 Hrs.	Forgot to bring in after odour.	BDL	BDL	BDL	BDL
Paget Res.	Apr 24'98 @ 0840	Apr 29 @ 1325	125.25 Hrs.	Brief odours. Forgot to collect samples for a few days.	1.2	1.1	BDL	0.6
Shell Caroline Area	Oct 29'97 @ 1248	Oct 30 @ 1515	26 Hrs. 27 Min.	No comments.	BDL	2.3	BDL	1.3
Shell Caroline Area	Oct 29'97 @ 1222	Oct 30 @ 1452	26 Hrs. 30 Min.	Both at the same site.	0.6	BDL	BDL	BDL
Shell Caroline Area	Oct 29'97 @ 1222	Oct 30 @ 1452	26 Hrs. 30 Min.	1 mi. N.E. of Shell Stack.	0.8	2.2	BDL	1.2
Air Quality Guideline					30 [a]	2000 [b]	4000 [c]	2300 [b]
Odour threshold [d]					4500	8025	8700	348

a Refers to Alberta interim one-hour guideline for benzene.
b Refers to Ontario 24-hour point impingement standards for toluene and xylenes.
c Refers to Ontario one-hour point impingement standard for ethylbenzene.
d Odour threshold obtained from Ruth (1986).
BDL Below analytical detection limit.

Volatile Organic Compound Concentrations in the Caroline/Sundre Area and at Other Locations in Alberta (ug/m^3)

Volatile Organic Compound	Median Concentration in the Caroline/Sundre Area	Median Concentration from 1991 to 1997 [a]		
		Edmonton Central	Edmonton East	Calgary Central
Benzene	1.2	2.7	2.0	2.9
Toluene	2.6	1.3	0.7	1.2
Ethylbenzene	BDL	6.3	3.9	6.8
Xylenes	1.2	6.2	3.5	6.0

a Based on samples collected using SUMMA canisters as part of the routine AEP air quality monitoring program.
BDL Below analytical detection limit.